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FRIDAY, NOVEMBER 18th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

ONE-HUNDRED-AND-SEVENTY-FOURTH SESSION, 1927-1928.

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NOTICES.

NEXT WEEK.

MONDAY, NOVEMBER 21st, at 8 p.m. (Cantor Lecture.) PROFESSOR H. C. H. CARPENTER, M.A., A.R.S.M., F.R.S., "Alloy Steels, their Manufacture, Properties and Uses." (Lecture II.)

WEDNESDAY, NOVEMBER 23rd, at 8 p.m. (Ordinary Meeting). T. HEDLEY BARRY, "Malayan Varnish Resins." A. F. Suter, Esq., will preside.

FUND FOR PURCHASING THE SOCIETY'S HOUSE

The following offer has been received from a Fellow of the Society:—

"As a help towards the Fund for purchasing the freehold and covering the cost of renovating and decorating the Society's House, I will add 5 per cent. to every contribution up to a total of £2,000 received from now to the end of June, 1928, for that purpose.

WM. RUSHTON PARKER, M.D."

The Council earnestly hope that friends of the Society will give them an opportunity of profiting by Dr. Rushton Parker's generous offer.

The total amount required is £50,000, of which £43,401 14s. 5d. has now been subscribed.

PRESERVATION OF ANCIENT COTTAGES.

PUBLIC MEETING AT WORTHING.

Under the auspices of the Royal Society of Arts, a public meeting was held at Worthing, on November 3rd, to consider what steps should be taken to ensure the permanent preservation of the three Thomas à Becket cottages at West Tarring. The property was recently put up to auction, and a sum was temporarily guaranteed (including £600 from the Society's Fund for the Preservation of Ancient Cottages), sufficient to buy it in.

THE MAYOR OF WORTHING (COUNCILLOR COOK), who presided, read letters from the Archbishop of Canterbury and Lord Winterton, warmly commending the objects of the meeting.

SIR FRANK BAINES, C.V.O., C.B.E., said that they saw in the work of the craftsmen who built the cottages at West Tarring an infallible appreciation of

real beauty. There was considerable difference of opinion as to the exact date of the cottages; he did not propose to dogmatise on that point, nor did he think it a matter of vital importance because, whether they dated from the late fourteenth century or the early seventeenth, they were things of beauty, and ought to be kept forever.

He then delivered an address, illustrated by lantern slides, on Ancient Cottage Architecture.

MR. F. BENTHAM STEVENS, secretary of the Sussex Archæological Trust, explained that the Trust had been formed for the purpose of looking after historic and interesting buildings, such as these cottages, and he stated that if, after they had been purchased, they were handed over to the Trust, they would be most carefully looked after for all time.

At the conclusion of the meeting the MAYOR expressed his willingness to open a Fund for preserving the cottages. A sum of £1,000 was wanted, and already £118 had been received, before any subscriptions had been solicited. He hoped that sufficient money would be raised to enable them to repay to the Royal Society of Arts Fund the whole of the £600, the timely production of which had saved these beautiful cottages from demolition.

SECOND ORDINARY MEETING.

WEDNESDAY, NOVEMBER 9th, 1927. THE HON. SIR ARTHUR STANLEY, G.B.E., C.B., M.V.O., Chairman of the Royal Automobile Club, in the Chair.

A paper on "Road Traffic Problems of the Pedestrian" was read by Dr. Mervyn O'Gorman, C.B., D.Sc., M.Inst.C.E. The paper and discussion will be published in the *Journal* next week.

INDIAN SECTION.

FRIDAY, NOVEMBER 11th, 1927. SIR HENRY STRAKOSCH, G.B.E., in the Chair.

A paper on "Indigenous Indian Banking" was read by MR. M. M. S. GUBBAY, C.S.I., C.I.E., General Manager, P. & O. Banking Corporation, Ltd.

The Paper and discussion will be published in the *Journal* dated December 2nd.

CANTOR LECTURES.

MONDAY, NOVEMBER 14th, 1927. PROFESSOR H. C. H. CARPENTER, M.A., A.R.S.M., F.R.S., Professor of Metallurgy, Imperial College of Science and Technology, delivered the first of his course of four lectures on "Alloy Steels, their Manufacture, Properties, and Uses."

The lectures will be published in the *Journal* during the Christmas recess.

PROCEEDINGS OF THE SOCIETY.

OPENING MEETING OF THE 174TH SESSION.

WEDNESDAY, NOVEMBER 2ND, 1927.

The Chairman delivered the following Inaugural Address :—

THE ROYAL SOCIETY OF ARTS: ITS SERVICES TO TRADE AND TRAINING.

By SIR PHILIP MAGNUS, Bt.,
Chairman of the Council.

As a sort of introduction to my address on the opening of the 174th Session of the Society, I may be permitted to refer to the recent adornment by Sir Aston Webb of what was a blank wall at the rear of the Society's House. It was he, who a few weeks ago received at the hands of H.R.H. the President of the Society the Albert Medal, for distinguished services to Architecture. The decoration was suggested and the cost was defrayed by Sir George Sutton, a member of the Council; and as some recognition of the Society's indebtedness to the generous donor, the Council invited him, as chief guest, to a dinner held at the Athenaeum on April 28th. It was on the morning after that dinner that I received a letter from Sir Thomas Holland, our past Chairman, in which he stated, "After you left the Athenaeum many of our colleagues suggested independently that it would be a popular and wise move, if we could succeed in persuading you to be Chairman of the Council for 1927-28. Don't say 'no' before reading further." Well! I did read further; and I am quite certain that owing to my age and to my lack of many of the qualifications expected from a Chairman of the Council, I should have declined the honour had it not been for the fact that the Council may have had in view such educational experience as I was supposed to have acquired, and that a Departmental Committee had been appointed by the Board of Education to enquire into a highly important part of the Society's activities closely connected with its educational work.

Such an enquiry involving written answers to a series of questions was a wholly new experience for the Society. Other learned bodies, as for example the London University, which has enjoyed the reputation of being even a more examined than an examining University, had been subjected to such enquiries. But not so the Society. In these circumstances, and after having read the whole of Sir Thomas Holland's letter, I acceded to his request, subsequently unanimously supported by the Council; and in the hope of being able to increase your interest in the work of the Society, I shall endeavour to show the

value of its services in the gradual development of that part of our national education affecting our trade and commerce.

Our Society was founded in 1754 under industrial conditions urgently in need of such service as it was the special object of the founders of the Society to render. It was a period of grave anxiety at home, and of no less difficulty as regards our relations with our more important colonies. The alliance between England and Prussia at the close of the year 1755 is said to have given the signal for the Seven Years' War in Europe; and it was owing mainly to the genius of our great statesman William Pitt, that our troubles seemed to have changed to a period of triumph in 1759.

But as regards our American colonies, owing possibly to our failure to have realised the spirit and character of the colonists, the result partly of their early establishment of a system of local schools in every small township, and to the consequent growth of an educated people; and owing equally to the weakness of our government at the time, the struggle for complete independence, which was eventually gained by the colonists, began to give trouble at home, and seriously affected, 170 years ago, the growth and development of our trade.

I need not remind you of the complete absence in this country of anything approaching, at that time, a national system of even elementary education, nor how the only instruction then available for the working, or the lower classes as they were then called, was that provided in the Sunday and Parochial Charity schools. As a fact, two-thirds of the people grew up without having received even rudimentary education, unable to read or write. Moreover, the heavy paper duty went far to counteract the advantages conferred by printing on the few who were then able to read.

In these circumstances the Society, when first founded, was unable to appeal to the unlettered public by means of lectures on Science or other subjects, nor was it able, by any effort, to improve or to supplement the very elementary teaching of the schools. To give effect, therefore, by any of those means, with which we are now familiar, to the essential objects which the founders of the Society had in view, seemed, as indeed it would have been, a hopeless task. They realised the need, and at the same time the necessity of inventing some new and hitherto untried machinery for satisfying that need.

I must ask your attention while I briefly refer to some of the activities which have engaged the thoughtful consideration of the Members of the Council of the Society since its foundation. It was Mr. William Shipley its first secretary who at a meeting of some dozen men of wide knowledge and experience, held in March, 1754, advanced cogent reasons connected with the condition at that time of our home Trade, for the Establishment of a Society, the main purpose of which should be the Encouragement of Arts, Manufactures and Commerce. By that title the Society was first known, its name having been subsequently abbreviated to that of the 'Society of Arts.' It was not till the year 1908, that King Edward VII., who, as Prince of Wales, had been for many years

President of the Society, granted permission to prefix to its title the word 'Royal.'

For the first year after the Society was founded Mr. Shipley acted as Honorary Secretary and soon after the Society had been formally constituted, he resigned the position of Secretary, which he had held for two years, and was appointed to the post of Registrar. For many years he was closely connected with the work of the Society, and from what one can gather from its history, as compiled by Sir Henry Trueman Wood, our past Secretary, Shipley may certainly be regarded as its founder.

What I desire to explain in this opening address is how the varied activities of the Society, and they were many, have been continuously directed to the development and improvement of our trade and commerce and how the Society was thus able to give valuable service in the training of artisans and clerks.

From the foundation of the Society and throughout its history, a marked characteristic of its policy has been the endeavour to avoid repeating or interfering with the work of other institutions having similar objects; or, to compete with what other bodies were capable of doing, possibly with ampler means and wider experience. This policy, by limiting to some extent the scope of the Society's activities added to its difficulties. Founded some 100 years after the Royal Society, the Council hesitated to follow their example of disseminating the knowledge of new discoveries by the reading of papers, descriptive of the results of fresh scientific researches. Its aims were essentially practical. Indeed it may be said that as the condition of England in the middle of the 17th century gave birth to the Royal Society and to a wide-spread interest in the investigations of science, so the condition of the country in the middle of the 18th century, brought about the formation of a Society for the encouragement of the application of science to all objects of public utility. And as with Science, so it was with Art. Not long after the foundation of the Society, a suggestion was made that the Council should apply for a Charter to form an Academy of Painting, Sculpture, etc. The Council refrained from doing so, and in the year 1768 the Royal Academy was founded. The Society was willing to give its aid to the formation of such an Academy, but realising how, having regard to the difference between the objects of the Academy in the training of artists and development of Art, and the objects of the Society in the application of Art to industry, the Academy might, and indeed would, have suffered from a fusion of both, declined to take part in the proposed scheme. Only a few weeks ago, the Society's interest in practical art-work was shown by the exhibition at the Imperial Institute of industrial designs of artistic value, applicable to textiles, furniture, book-production, china, glass, and other subjects, for excellence in which money prizes and scholarships to the value of £1,200 were offered by the Society on the results of a wide competition.

During the first century of the Society's existence and for some years after, its main activity was to award prizes of money and medals as premiums for

meritorious discoveries and inventions, and for other objects likely to advance manufacturing industry and to facilitate commerce. The Society received no subvention from the State ; it was independent of such aid, and like some few other institutions, was consequently free to advance along its own lines. Its funds were obtained from the subscriptions of its members and from gifts and legacies to be applied to special purposes approved by the Society, or for other objects cognate to those for which the Society was founded. " The first impression on a survey of the Society's work," wrote Lord Sanderson, in his preface to Sir Henry Trueman Wood's history, " is one of some bewilderment at the multiplicity of the subjects with which it dealt in rapid succession or even simultaneously."

To a few of these illustrative subjects I must refer, if only to show how the award of such prizes influenced other efforts, and in no small degree, the advance of education on its practical side. Moreover, in looking back through the history of the Society, one cannot fail to be struck with its apparent vision of coming events. It anticipated much that lay hidden in the future, and prepared the way for the building-up of new institutions for the advancement, by other methods than its own, of our trade and commerce.

It is of some interest to note that the Society's early efforts were largely exercised in the endeavour to develop the resources of the British Colonies. As early as 1758, a prize of £100 was promised for " Five tuns of good wine made in a plantation in any colony (America not excluded, there was no prohibition then) provided that one tun was imported to London." As an instance of a very different offer, I may mention that in the year 1756, the offer was made of a prize to the person " who should plant and properly fence the greatest number of white mulberry trees in his own plantation in the province of Georgia."

The Society appeared very desirous of creating a home industry in the manufacturing of silk. In 1768, a prize for " English raised Silk " was offered, and from that date great efforts were made to encourage the planting of mulberry trees in this country. Those efforts failed ; but as an instance of the Society's seeming prevision, I cannot refrain from drawing attention to the paper on " Artificial Silk " read by Mr. Thomas Brough, to whom this evening the Society's Silver Medal will be presented.

The award of prizes to America ceased with the Declaration of Independence by the colonists in 1775 ; but for some years later the prizes offered were open to all colonists in other parts of the empire, showing the sense of Imperial Unity, which marked the early efforts of the Society in its endeavour to encourage, not only in this country, but throughout the Empire, improvements in manufacturing industry and commerce.

Subsequent to the secession of the American colonies from the Empire, the Society prepared a list of suitable objects for its premiums.

The classes under which rewards were arranged were varied from time to time, but eventually they were distributed among different committees each

dealing with a separate group of the following subjects:—1. Polite Arts. 2. Machinery. 3. Manufactures. 4. Mechanics. 5. Chemistry. 6. Colonies and Trade.

"Polite Arts" included practically all that is generally understood by "Applied Art" such as the specimens recently exhibited at the Imperial Institute. Agriculture included Forestry. By Chemistry was understood industrial chemistry and other branches of applied science. Manufactures and Mechanics were not clearly differentiated. The number of standing Committees was subsequently reduced to Sections for India and for the Dominions and Colonies. Other Committees have been constituted as required.

The time at my disposal permits reference to a few only of the different objects for which premiums were offered. They serve, however, to show the character of the work in which for many decades the Society was engaged. Among its earliest efforts to promote and improve Agriculture was the offer of prizes for the planting of forest trees. Forestry or Arboriculture was at that time little understood, and our dependence on foreign imports of timber was very marked. Many years ago the Society realised this need. Between the years 1758 and 1821, 127 gold medals and 40 silver medals were awarded for the planting of trees. The offer was discontinued in 1846, but mainly owing to the Society's encouragement, the number of trees planted during those years must, we are told, have exceeded 50 millions. The last award for tree-planting was made in the year 1835.

Very different were the awards made for the improvement in the manufacture of textiles, for which during the first 20 years of the Society's existence, as much as £1500 had been expended in premiums. These awards covered a great variety of inventions, some of which, but not all, proved of great value in enabling goods to be produced in this country which had previously been imported from abroad.

Among many interesting awards I may mention that in the year 1825 a silver medal and fifty guineas were won by the inventor of an apparatus to enable persons to breathe in thick smoke, or in air laden with suffocating vapours. A dense fog may have been familiar to Londoners a century ago; but the inventor of the apparatus could not, except by the gift of prophesy, have known the value of such an invention as a defence against the poison-gas from which our soldiers suffered in the Great War.

Mistakes were sometimes made, and we must remember that a century ago inventions tending to substitute machine-work for hand-work were not received with general satisfaction, but were believed to have the effect, which possibly they had for a limited time, of increasing unemployment. Indeed, in the first half of the 19th century, the hatred of new machinery was combined with strikes in certain trades, and the workers did what they could to prevent improvements in the tools they used. The Society was not discouraged by its occasional failures; its efforts, however, were somewhat restricted by its

opposition to patents. No premium or medal was given to an inventor who patented his invention or discovery. Prizes were given to those only who, like members of the medical profession, published their discoveries for the public good. Not until the year 1844 was the rule abolished and the restriction removed.

The character of the awards during the last quarter of the 18th century was largely due to the fact that in the year 1769 James Watt took out his first patent, and the modern steam engine came to be applied to the substitution of mechanical for horse and hand power in many different branches of industry. A large number of inventions were rewarded by the Society during that eventful period ; but gradually the number of applicants decreased and the offer of such prizes was discontinued in 1821. The few examples to which I have referred suffice to show how the offer of money prizes by the Society in the early years of its activities helped to encourage improvements in different branches of industry.

As I have said, the services rendered by the Society to Trade did not cease with the withdrawal of their premiums and prizes. They changed with the changing needs of industry and commerce. Early in the 19th century it was suggested that instead of the award of money prizes for inventions, courses of lectures should be given and papers should be read by competent authorities on discoveries affecting improvements in manufacturing industry, and that in this way a large measure of useful information would be disseminated to the general public. Evening meetings were accordingly arranged at which, then as now, such papers were read and discussed. In 1845, the reading of papers was encouraged by the decision of the Council to prepare a form of honorary testimonial to be presented to persons whose papers appeared to be deserving of such notice. The silver medals to be presented this evening are the outcome of that decision.

In addition to the funds provided by the Council for awards, numerous gifts have been made to the Society for prizes ; and legacies have been received for the endowment of lectures and for the award of premiums for essays and other objects. I can only mention a few :—The Cantor Trust under which the Society's well known courses of lectures on various branches of Applied Science are delivered every session ; the Thomas Gray Memorial Trust for the advancement of the science of Navigation ; Dr. Mann's Trust of £1,000 for courses of juvenile lectures to be delivered yearly ; the Swiney Trust of £5,000 for prizes to be given from time to time to the author of the best published work on Jurisprudence ; and many gifts such as the Henry Trueman Wood Fund and the Sir George Birdwood Memorial Trust have been received for the endowment of lectures in recognition of distinguished services to the Society.

During the years following those to which I have referred various suggestions were made for modifying the work of the Society with a view to bringing it into closer relation with the changed conditions of Trade and Commerce. These

altered conditions were largely due to the economies effected in output by the application of scientific methods, and to the wider interest shown in the advances of science. Those advances resulted then, as within the last few years, in improved conditions of communication and transport, and the activities of the Society were modified accordingly.

The new era opened with the acceptance of the Presidentship of the Society by the Prince Consort in the year 1843. Without attempting the thankless task of assigning the share of credit due to the Prince for the thought that gave birth to the Exhibition of 1851, or of weighing the work done by Sir Henry Cole, who was Chairman of the Council in the years 1850-52, we may certainly ascribe much of the success of the first Exhibition, especially in its educational influence, to the Prince's persistent efforts to make others realise, as he realised, that effect could best be given to the many objects of the Society by popularising the belief in the advantages that would necessarily follow from the application of Science and Art to every form of industry. There can be no doubt that in many ways the Exhibition of 1851 gave a strong impulse to the promotion of technical and commercial education. It provided the means of comparing the products of our shops and mills with those of other countries, and brought into strong relief the bearing of Art on manufactures and the possibilities of improvement that might follow from the alliance of industry and science.

The change so effected was very great and productive of results previously unexpected and unrealised.

Before the opening of the great International Exhibition it was suggested by the Prince that a series of lectures should be given by eminent experts on the principal objects exhibited. These lectures were duly delivered. They were mainly intended to show the bearing of science and art on industrial products, and the fresh ideas to be derived from some of the exhibits. The series was closed by a highly interesting lecture on the "International Relations of the Exhibition."

Between 1851 and 1862 and long after, even to the present day, the Society helped to arrange special local exhibitions, which were followed by somewhat similar displays in other countries. These early exhibitions undoubtedly proved the starting point of educational movements of supreme national import.

As early as 1836 a grant of £1500 was made by the Government towards the establishment of a School of Design. It was not, however, till some time after the Great Exhibition was closed that any systematic State aid was given to the teaching of Science and Art. In a speech from the Throne at the Opening of Parliament in 1852 reference was made to the subject, which led to the establishment in 1853 of the Science and Art Department under State control. About this time a system of money grants in aid of Science and Art classes was established, applicable to the entire country, the grants being made on the results of the examination of the students. The system was known as "Payments by Results" and was described by Huxley as "A

capacity-catching machine." It may have been, but if so, it was a machine, on the accuracy of which one could not always rely. In an address I gave on "Technical Instruction in England," at an International Conference held at Bordeaux in the year 1886, I described this unique system of payment. My address was duly noticed in the Paris daily paper, *Le Temps*, of September 24th of that year, and the system of payment was described as "Un système fort original, où se reconnaît l'esprit éminemment pratique des Anglais... Les subventions ne sont pas données en bloc aux écoles, elles leur sont attribuées suivant la valeur des élèves qu'elles forment. C'est ce qu'on appelle le payement d'après le résultat."

The writer of that article anticipated the all-important changes made later on by the payment of block grants to our schools.

The Exhibitions of 1851 and 1862 and those that followed them directed attention to the all-important work of education, and the Society was not slow to discover the means of supplementing to some extent the education given in day schools, by specialised evening instruction applicable to different trades and occupations. Independent efforts in that direction had been made by the foundation of Mechanics' Institutions, with which the name of Dr. Birkbeck will ever be associated. In 1848 the Society identified itself to some extent with those efforts by enabling the Institutions near London to become members of the Society on the same terms as individuals. The Institutions for some years did excellent work. They were said to have sprung up as by magic. In the year 1841 there were already 220 of such institutions of which 36 were in or near London. The Society recognised that these Institutions, scattered through the country, might prove to be helpful in giving effect to some of its original objects, and a Conference was accordingly held in 1852, at which a Union of such Institutes was formed. In the following year, as many as 270 Institutions had joined the Union, and in connection therewith a small Exhibition of Educational Appliances was held at the Guildhall. Later on, owing mainly to the lack of funds, the greater number of these Institutes degenerated into cheap Reading Clubs for the middle classes. But they had done their work. They afforded during many years of educational obscurity a glimmer of light, which enabled the more gifted of our working men to search in other quarters for the knowledge they needed.

The Exhibition of educational apparatus and appliances initiated by the Society proved to be a great success. Courses of lectures were delivered by a number of distinguished educational authorities on subjects closely allied to the objects of the Society. After the close of the 1851 Exhibition and the purchase of the Kensington Estate from its proceeds, the Society was invited to co-operate in the formation of a great Trade Museum, an idea which it may be said has to some extent found expression in the Museum of Oversea Products, now located in the Imperial Institute. The Education Library recently removed from South Kensington to Whitehall, and the Victoria and Albert Museum

can trace their origin to the developments resulting from the work of the Society in close connection with the Union of Mechanics' Institutes. That work led to the organisation of Educational centres for local Science and Art classes throughout the country, and, as early as 1853, to a system of examinations for the special benefit of members of the Union, which resulted later on in the wider scheme of examinations in Technology and Commerce.

The Society's examinations, which may now be regarded as a factor in the organisation of commercial education in this country, started, as I have said, as an adjunct to the work connected with the Union of Mechanics' Institutions. Examinations, as an essential part of our educational system, were not as common 70 years ago as they now are. The scheme of instruction on which the Society's examinations were based was, as originally drafted, very comprehensive. It included many of the subjects embraced in a liberal education. The first examination was held in 1854, at which only one candidate was presented; two years later, after the scheme had been somewhat curtailed, 62 candidates were examined in the Society's House. In the following year, the first of our provincial examinations was held, which before long were extended to the whole country. The Society cannot, however, lay claim to have been first in the field of local examinations. After considering various suggestions for the inspection and examination of schools, the College of Preceptors, practically a college of teachers and for the training of teachers, founded in 1846, organised in 1854 a system of local school examinations. These preceded those of Oxford, Cambridge and London, just as the Society's examinations preceded those of the Science and Art Department of the Board of Education.

For some years, indeed till 1857, the Society's examinations were conducted by a Board of distinguished scholars, who gave their services voluntarily; but later on professional examiners were appointed and received fees. During those early years, when the examinations covered the subjects of an ordinary school education, and until the introduction of competitive examinations for Civil Service appointments, the Government placed at the disposal of the Society some few clerkships in the public offices, on the results of examinations held by the Society. Later on, owing largely to the Society's unwillingness to compete with other examining bodies, it was decided by the Council to restrict their efforts to educational work more closely associated with its originally accepted objects; and accordingly in 1876 a new scheme was prepared, with a view to giving direct encouragement to the study by artisans, clerks and others of subjects closely connected with their trade or craft.

About this time, mainly as the result of the International and other Exhibitions held at home and in other countries, there was a growing feeling that many of our manufactured products compared unfavourably with foreign goods, and that those engaged in the work of distribution—in selling our home-made products here and abroad, were not as well trained as those educated in some of the best foreign commercial and trades' schools. As early as 1867 Sir

Lyon Playfair warned our people that owing to the practical instruction provided elsewhere, the industrial advance on the continent was more rapid than at home. There was a general demand for more specialised, or for what is now known as technical education. Conferences were held, and in 1871 a proposal was made for the introduction of Technological Examinations to supplement those of the Science and Art Department, which were found to have no direct reference to the trades in which the students were engaged. I have always heard that the restriction of grants made by the State to the teaching in these schools of the elements of different branches of science, or of what may be called "pure Science," was owing to the Government's scrupulous adhesion to the tenets of Free Trade, and that the payment of grants for instruction in the application of science to special industries would have been regarded as equivalent to the safeguarding of those industries, and consequently opposed to the tenets of Free Trade as then understood. Be that as it may, a new and wider scheme of instruction was prepared and considered at a Conference over which the Duke of Connaught presided, and the scheme so prepared was intended to suggest courses of study on which examinations would be held adapted to the vocational requirements of artisans engaged, or preparing to engage, in recognised sections of different trades. In the first year the number of candidates was only six, but the number went on gradually increasing.

Meanwhile, certain of the Livery Companies of London, eager to take part in the generally expressed desire that some scheme of industrial instruction should be provided, and realising that such action would accord with the objects for which they were originally founded, appointed a Committee of their own members to consider generally the question of the extension and improvement of technical education; and among their suggestions was the proposal that examinations should be held in subjects to be taught in trade schools, and that certificates of merit and prizes should be awarded in connection therewith. On the report of the Committee, the City and Guilds of London Institute was established, and adequate funds were subscribed for giving effect to its proposals.

In 1879, the Society of Arts, knowing that the City Guilds Institute would be enabled out of its newly subscribed funds to pay grants to teachers and so to encourage the formation of local Evening Trade Schools, transferred to the City Guilds the conduct of its technological examinations and confined its efforts to the encouragement of commercial instruction by the further development of its own examinations. From the small beginnings to which I have referred the number of entries for the City Guilds examinations prior to the War exceeded 24,000; and after certain re-arrangements, partly suggested by the Board of Education, the entries this year, including those in handicraft, were 14,205. Meanwhile, the number of candidates for the Society's Commercial examinations continually increased, and, including the pupils from Day Schools

who entered for special examinations, recently introduced at the request of the London County Council, has this year exceeded 65,000, the number of separate papers worked being 88,088. In the conduct of its examinations the Society is now assisted by a Committee of the Council, on which are represented teachers of Commerce, local Education Authorities, Business men and H.M. Inspectors of Commercial classes.

In the month of March of this year a Departmental Committee was appointed by the Board of Education "To enquire and report as to the arrangements for "the examination of students attending part-time 'chools (excluding art "schools) under the regulations for further education with particular reference "to the place and value of examinations as an element in training for industrial, "commercial and professional activity."

The appointment of the Committee is an important incident in the long life of the Royal Society of Arts. The Society in common with other bodies, holding examinations for part-time students, has been asked to reply by written answers, to a number of questions, a list of which has been received; and I need scarcely say that the Council of the Society will do what they can to satisfy the Committee as to the character and commercial value of the examinations, which they now conduct.

The Committee appointed by the Board of Education is especially asked to enquire into "the place and value of examinations" as an element for industrial activity. The question of the value of examinations as an educational factor opens up a very wide subject of enquiry, and the appointment of the Committee may help in directing attention to the different kinds of examinations, and the purpose which each is intended to serve. There has been a growing belief in their value as testing the capacity of candidates to enter different professions, such as the Law, Engineering, Architecture, Accountancy, Hospital Nursing, etc. Medicine has never wavered in its recognition of the value of entrance examinations. Differences of opinion, however, do exist as to the relative value of what are known as "external" and "internal examinations"—of those conducted on the one hand by men of distinction in their profession or business, who may not have had practical experience as teachers, and on the other hand, of examinations in which the teachers of the candidates have at least taken some part in the setting of the questions and in marking the answers of the candidates. The divergence of view as to the relative value of these alternate forms of examination has been brought of late into prominence by the fact, that the teachers of our day schools and of our evening technical and commercial classes are of a far higher and wider standard of education than was the case some 30 or 40 years ago. Teachers so qualified rightly feel that they are more competent by their intimate knowledge of the acquirements and character of their pupils to judge of the fitness of the candidates for whatever the examination is intended to discover, than the external examiner who can judge by answers only to written questions, even when supplemented by oral

discussion. There is much to be said in favour of this view ; and in all our Universities and especially in our single college universities, this view has prevailed ; and when the teacher is assisted by an external examiner, whose function should be to see that the questions are not too exclusively confined to the subjects as taught, the internal examination may prove a better means of testing, not only the acquired knowledge, but also the capacity and to some extent the character of the student, than when the questions are set by examiners, who have had no personal acquaintance with the candidate.

But there is also much to be said on the other side, and necessity asserts itself where practical and other conditions have to be considered. When, for instance, a large number of candidates from schools and classes, widely separated, present themselves, the examiners appointed are unable to share their duties with the teachers of the schools. Moreover, when the external examiner is a man of wide knowledge and great experience, his questions, whilst well within the syllabus, may prove suggestive to the teacher of new facts and fresh ideas and of other aspects of the subject, which may be helpful to the teacher and of value to the taught. A further advantage of external examinations, conducted by a body of established reputation, is that uniform standards of merit can be secured common to the several classes of students examined, which enable employers to gauge the knowledge and ability of applicants for employment.

For these and other reasons the Society's examinations meet a wide-spread demand, which cannot be disregarded ; and it may be assumed that the Council of the Society with the assistance of their commercial Committee will, from time to time, modify and adapt the subjects for examination to changing conditions of trade and commerce and of educational requirements.

The late Lord Reay, speaking some years ago on the question of commercial education, stated that special instruction was needed for clerks, travellers, the heads of mercantile houses and Banks, and for those preparing to enter the Consular Service.

Our local Education Authorities, with the assent of the Board of Education, have not been unmindful of the importance of providing commercial teaching in some of the classes of our elementary and secondary schools. More advanced instruction is given in evening classes closely associated with the Society's examinations. Since the beginning of the present century, progress has undoubtedly been made in the endeavour to make our secondary education a fitting foundation for vocational work. The weekly lectures delivered in this Hall have drawn public attention to existing needs. There may be some here present who can remember the late Walter Besant's description of the German clerk, as introduced in one of his novels,—the clerk who could speak, and write in nearly every modern language, and who is supposed to have said : " We are learning your trade, we will find out all your customers and your correspondents ; we learn your profits and we undersell you. We do not go away,

we remain. And presently, instead of an English house there is a German house in its place because your young men are so stupid that they do not learn."

I quoted that passage in a paper on Commercial Education, which I read from this platform in the month of December 1887. That address was followed by one by the late Sir Albert Rollit in 1897, in which he gave many extracts from various Consular Reports as to the courses of study pursued in foreign commercial schools. Public attention was thus drawn to such of our educational needs as affected our home and foreign trade. Those defects in our secondary education, so forcibly described by our novelist, no longer exist. Moreover, it is now recognised that commercial instruction can be co-ordinated with what is generally understood by a liberal education, and that the subjects involved in such a training can be so taught as to yield much of that wide culture, which it might be thought can only be acquired by other studies.

The instruction provided in the Day classes recently organised by the London County Council is intended to serve as the foundation for a wide range of vocational work. In the Central Schools of other Local Educational Authorities similar instruction is already, or may be before long, provided, and the pupils of such schools are likely to be entered for the Society's Day School examination, which was held this year for the first time. That examination, modified as it may be with changing Trade Conditions, might take the place of the much needed "leaving examination" to which Lord Eustace Percy referred in a recent speech at Tunbridge Wells, in connection with the National Chambers of Trade, and to quote his words might come to have a "recognised value in enabling those who pass it to secure good employment." If so, our Society might render a great service to many occupations other than Commerce.

Where our scheme of commercial education may be said to have been deficient until very recently, was in the higher grades of teaching, as supplied by our Universities. Since then however, active steps have been taken to remedy that acknowledged defect.

It was from the city of Birmingham that we were first urged "to think Imperially," and the University of that city was the first in England to grant degrees in Commerce. In London, at a meeting in 1892 of the old Senate of the London University, before it was changed from a mere examining, as was said, to a teaching university, a proposition was made to institute a degree in Commerce. The proposal was referred to a Committee who reported against it. Some 20 years later, at a meeting of the Senate, as reconstituted, it was agreed that a degree in commerce should be instituted; and in the month of May, 1919, less than 10 years ago, the proposal was approved by H.M. in Council. As a matter of interest, I may mention that at the public presentation of degrees on 5th May, 1921, H.R.H. the Prince of Wales received the honorary degree of "Master in Commerce"—the first commercial degree conferred by the London University. Since then, in London alone 261 students have graduated in Commerce, most of whom have attended the various courses of lectures,

at the London School of Economics. As showing the demand for the higher grades of commercial instruction, six out of eight Universities in England, those of London, Manchester, Birmingham, Liverpool, Durham and Leeds, omitting the Universities of Oxford and Cambridge, have now arranged to confer degrees in Commerce, and the total number of students who have graduated in that Faculty from the Provincial Universities and London is 892.

In recording the progress made during the last decade in the supply of funds for the teaching of the Science of Commerce, a note must be added of the successful efforts of the late Sir Sydney Russell-Wells, who, as M.P. for London University, succeeded in obtaining large sums of money from Banking Firms and heads of Business houses in this country, and especially from Sir Felix Cassel, of whose generous contribution a substantial part was allocated to the foundation of travelling scholarships. Such Exhibitions and Scholarships are greatly needed, seeing *inter alia* how essential it is that our manufacturers and merchants should be made fully conversant with, and able to supply, the kinds of goods that our colonial and foreign customers desire to purchase, rather than the goods which our business houses may be anxious to sell. On these and other points our manufacturers and merchants must have reliable facts and it is to our well trained commercial scholars, that they should look for such trustworthy information.

It may be accepted as an axiom, that the three principles which should determine all professional training are: 1st. To secure a good general education; 2ndly, a good scientific education, and 3rdly, good technical instruction. There can be no doubt that these three grades of education are essential for those preparing for the higher branches of commercial life. Commerce has become a science and an art, and the degrees in Commerce granted in some of our Universities for Bachelors and Masters are specifically indicated and conferred as degrees in Science (Com.) and Arts (Com.).

In London, as stated, a large and increasing number of students, preparing for degrees in Commerce, graduate from the London School of Economics, where courses on the essential principles of Economic Science, as underlying the various branches of business activity, are given by Professors, Teachers and Readers of marked distinction.

As supplementing, without competing with, or overlapping the work of the London School, help might be afforded in popularising the higher grades of commercial training, if a wider use were made of the vast and well-arranged collections of colonial and foreign products now housed in the galleries of the Imperial Institute. Such collections on a much smaller scale, known as Museums, are found in most of the High-Schools of Commerce abroad, and there can be no doubt that a large number of students, now preparing for examinations in the higher grades of commercial work, would welcome the opportunity of studying, under the guidance of competent instructors, the materials, colonial products, and other exhibits now on view at the Institute.

Special arrangements have already been made by Lt.-Gen. Sir William Furze, K.C.B., the able Director of the Institute, for the visits of large numbers of our school children to the Institute, where displays of films illustrating the life and industry of the Dominions and Colonies have been fully explained in lectures by competent teachers. We have reason to hope that before long similar opportunities will be extended to older students, who have attended any of the now widely spread classes in Commercial Subjects, and to other students, some of whom may have graduated in Commerce, to reap the full advantage of examining and learning what may be learnt of the materials and industrial products imported from our Dominions and Colonies.

It would seem, having regard to the proximity of the Imperial Institute to the Imperial College of Science and Technology, that Commerce students might find in the College that training in Science so stimulating to all who may be preparing for a professional or business career—a training which, apart from its other values, may prove psychologically helpful to the Commercial traveller, or to the Manager of a Business Firm. Indeed, for success in either capacity such knowledge is essential.

The Annual Report of the Director of the Institute, submitted in February last to the Board of Governors, contains a detailed notice of the work now in hand, or about to be undertaken, in its various departments. Full information is given in that Report of the varied services which the Imperial College, of which Sir Thomas Holland, our past distinguished Chairman, is the Rector, renders to our Trade and Commerce, especially by the valuable research work now undertaken in the College, and not only there, but also, by expert Chemists, in the laboratories of Universities here and abroad, and in co-operation with other Institutes and Commercial organizations.

It is difficult to forecast the extent of the knowledge, serviceable in any branch of Commercial activity, that might be gained by associating the science training available in the College with the close study of the classified materials and other objects now on view in the galleries of the Institute, supplemented as that study might be by specialised instruction by competent teachers, with personal knowledge of such subjects as the Conditions of Life and Labour, of Manufacturing Industry and Commerce, as found in our Dominions and Colonies over-seas.

By the further extension of such joint action as is now in operation, the two great educational institutions, standing so near to each other on the site purchased out of the proceeds of the 1851 Exhibition, originally established for Imperial objects—the one for the advancement of Science and its application to Industry, and the other for the development of Trade and Commerce within and beyond the Empire—might largely assist in promoting what may be regarded as the more technical side of Commercial Education, and thus render ever-increasing service to our Country.

And in the Future, as in the Past the Royal Society of Arts has by its awards of premiums and prizes given an impulse to many activities for the encouragement of technical and commercial training, might now utilize the results of its annual examinations of many thousands of students to select some few who, by means of grants-in-aid, as prizes, would be enabled to profit by the higher grades of industrial education, as provided by the close co-operation, with this great object in view, of the Imperial College with the Imperial Institute.

The Chairman then presented the Medals for Papers and Lectures given during the last session, as follows :—

Papers read at the Ordinary Meetings :—

Thomas Brough, J.P., Chief Designer, Messrs. Courtaulds, Ltd., "Artificial Silk."

Warre S. Bradley, F.C.I.S., Secretary, Messrs. Watney, Combe, Reid and Co., Ltd., "Industrial Welfare in Practice."

William J. U. Woolcock, C.B.E., General Manager, Association of British Chemical Manufacturers, "Some Aspects of the Chemical Industry."

Clifford Copland Paterson, O.B.E., M.I.E.E., F.Inst.P., General Electric Company's Research Laboratory, Wembley, "Some Studies in Connection with the Manufacture of Electric Lamps and Thermionic Valves."

Francis H. Carr, C.B.E., F.I.C., President of the Society of Chemical Industry, "Insulin and its Manufacture."

C. S. Orwin, M.A., Director, Institute of Research in Agricultural Economics, University of Oxford, "The Transition of Agriculture."

Papers read in the Indian Section :—

Sir James B. Brunyate, K.C.S.I., C.I.F., "The Report of the Indian Currency Commission."

Cecil Henry Bompas, C.S.I., "The Calcutta Improvement Trust."

R. Mather, "The Iron and Steel Industry in India."

B. C. Allen, C.S.I., "Assam."

Paper read in the Dominions and Colonies Section :—

J. H. Oldham, Secretary of the International Missionary Council and Member of the Colonial Office Advisory Committee on Native Education in Tropical Africa, "Tendencies in African Native Education."

Trueman Wood Lecture :—

R. J. Tillyard, M.A., Sc.D., F.R.S., F.L.S., F.G.S., F.E.S., Chief of the Biological Department, Cawthron Institute, New Zealand, "The Progress of Economic Entomology (with special reference to Australia and New Zealand)."

Sir George Birdwood Memorial Lecture :—

Sir E. Denison Ross, C.I.E., Ph.D., "The Arabic History of Gujarat."

SIR THOMAS HOLLAND, K.C.S.I., K.C.I.E., D.Sc., F.R.S., said it was one of the privileges of an ex-Chairman of the Council to show his joy on leaving office by proposing a vote of thanks for the Inaugural Address of his successor. That evening the joy he had—of a different sort—was shared with his hearers in the certainty that for the coming Session the Society would have one to guide it during a time

which might be difficult for the Society, because of the great questions to which reference had been made in the Address. The whole question of the Society's Examination policy would come under critical review. On previous occasions when the activities of the Society had so been reviewed it had always taken the right turning. This time at any rate they knew the Council had been careful in choosing the right guide.

Only those who had studied intimately the history of technical education in this country could fully appreciate the hidden values of the Address. Nevertheless, it was probable that most of those present had a much more conscious idea of the value of the Address than Sir Philip himself. Since the 70's of the last Century, Sir Philip had been a prominent figure in a very small group of distinguished men who had cultivated the seed which had been first sown by Prince Consort when President of the Society, and his judgment now on rival schemes of education was the result of an experience in length and—what was more important—in intimate intensity of study which was absolutely unrivalled among living authorities. Sir Philip was probably quite unconscious of the varied processes of thought, or of the numerous and diverse impressions which had led to his present views on educational problems. The result was that his most casual thought on any one of them had a value which it was difficult for any later generation to appraise. One might possibly be able to reach some of Sir Philip's conclusions by studying the enormous mass of literature that had resulted from the controversies over the question. One might do so—but just imagine the difference between the man who swallowed Blue Books as the result of the various Royal Commissions and Committees which had dealt with the problem, and the man himself who had been a member of most of those Commissions and Committees which had moulded our educational policy since 1881. It was in 1881 that Sir Philip was appointed a member of the Royal Commission on Technical Instruction in this country. That was 46 years ago—long before at any rate any of the Society's lady members were born! Even then Sir Philip had been a veteran among educational authorities. At that time he had also been the Director, and one of the most active founders, of the City and Guilds Institute—an Institute which had done more probably than any other single British institution in influencing the trend of technical instruction in this country and in many parts of the Empire overseas. When one used the word "history," one's mind naturally turned back to the more distant past, and as such the Address was really a very valuable fragment of history; but that was not the most important or most interesting feature of it. The most interesting feature of the Address he could describe by a little incident which had occurred this summer, of the kind that the evening papers might describe as dramatic. When Sir Philip had accepted the invitation to be Chairman of the Council, a friend of his (Sir Thomas's) had remarked that it would give a little thrill to the old City and Guilds Institute to see their old Director and Founder again coming back to them in an *ex-officio* capacity as a member of its Council; but his friend had not been in full possession of the facts. The fact was that the old City and Guilds Institute would not realise that thrill: Sir Philip was already, in his personal capacity, not only a member, and an active member, of the Council of the Institute, but a member of its Executive Committee and of its Technology Committee. And Sir Philip was not one of those who was living on the memories of a glorious past. He was still one of the most active, one of the most enthusiastic—he thought he might say, one of the youngest of workers in the cause of education. As Chairman of the Society's Examination Committee, Sir Philip was responsible for what was now the biggest examination system in the world. He was responsible for the destinies, or at any rate the training of the minds, of anything between 60,000 and

70,000 young men and young women every year. As a member of the Council his regularity of attendance had made most of the other members of Council blush when every year the Secretary, according to the bye-laws, presented the record of work. Then, too, he was still an active member of the Senate of the University of London, and he was a member of the Council for External Students. They had in that way another instance of Sir Philip's continued interest in the so-called external type of University, as well as of the external type of elementary education. He had shown his interest in active ways in education that could not be described without giving a list almost as long as the Address. For sixteen years—and this showed Sir Philip's real devotion to the cause of education—he was a Member of Parliament representing the University of London. Many would remember that bitter controversy between the external and the internal side. Many would recall the feeling that had been caused by the great protagonists, who could see only one or other of the two alternative sides. Sir Philip, with his wider outlook, had been enabled to realise that the two were not antagonistic but complementary, and that both served their useful purposes. Sir Philip was conscious also of the fact that, whilst those who were devoted to the internal side of education could handle the destinies of hundreds, he, through the machinery which he controlled had been handling and influencing many thousands. Sir Philip was himself the product of an internal school, because it was now just 64 years ago since he had graduated with a double degree in Honours from University College. He was therefore able to look at both sides of the question; and personally he had no doubt that after the Address which the audience had heard that evening they would allow him to convey to Sir Philip on behalf of the meeting, as he did on behalf of the Society, their most sincere thanks.

Mr. Alan A. CAMPBELL SWINTON, F.R.S., seconded the motion, which was carried unanimously.

SIR PHILIP MAGNUS, in acknowledging the vote, said he had never been more nervous than when he knew that he had to say something about education. If there was any subject which kept an audience away it was education. He had tried to get out of the difficulty by not using the word "education" on the cards of invitation; he had put "training" instead. He was exceedingly grateful to Sir Thomas Holland, at whose suggestion he had undertaken his present onerous duty, and he had to thank the audience very much indeed for having listened with so much attention to what he feared had been a very uninteresting lecture.

The meeting then terminated.

NOTES ON BOOKS.

RECENT ADVANCES IN ORGANIC CHEMISTRY. Fifth Edition. By Alfred Stewart, D.Sc., Professor of Chemistry in the Queen's University of Belfast. London: Longmans, Green & Co., Ltd. Two vols., each 21/- net.

Twenty years ago, such text-books of Organic Chemistry as were published in English were inclined to be, if not dismal, at least somewhat dull productions. In 1907, however, there appeared Cohen's *Organic Chemistry for Advanced Students*, closely followed in 1908 by the first edition of Stewart's *Recent Advances*. The two are to a great extent similar in general character; each has had a success

resulting in the publication of a number of editions; and each has enormously expanded since its first edition.

Though the method of dealing with the subject was something of a new departure in text-book literature, it was already in common use by lecturers, who naturally are in a position of greater freedom with respect to their choice of matter. Instead of working through a conscientious list of organic compounds, dealing faithfully with the preparation and properties of each, one chooses an interesting group of substances, traces the relationships between them, explains the reactions involved in the various syntheses and investigations of constitution, possibly showing how these reactions are but special examples of general tendencies, and then passes on to another group.

It is hardly necessary to remark that this method is but a partial one. Many substances, ranking as of the first importance in more systematic schemes, are here liable to complete exclusion; and it is quite recognised that the present kind of treatment, while it undoubtedly brightens the life of the student, and increases the range of his perceptions in an extremely valuable manner, yet needs to be both preceded and accompanied by reading of a more pedestrian nature.

The new edition of Dr. Stewart's book is published in two volumes. This is partly a mere mechanical result of the accumulation of material, which has by now grown to nearly three times its original bulk; but in addition the two volumes have intentionally been made to differ in character, the first being mainly devoted to subjects on which general agreement may now be said to have been reached, while the second is more speculative in outlook, and is recommended more particularly for the use of honours students and graduates.

It is interesting to note that advantage has been taken of the extra space available in the present edition to restore certain of the original chapters which had been cut out owing to the increase in the number of groups discussed; the author having become aware that, if this process of exclusion were allowed to continue, some of the fundamental bases of the subject would have to be rejected, and "the work would degenerate into a series of scrappy summaries lacking in any instructive value." This misfortune has certainly been avoided, and it is to be hoped that the new edition will have a success equal to that of its predecessors.

THERMOMETRIC CONVERSION CHART; for the use of Mathematicians, Chemists, Physicists, Schools, etc. By Percy L. Marks. London: Crosby Lockwood & Son. 3/6 net.

The make-up or general aspect of this chart may be defined as a quarto volume in boards, but so thin that if opened out flat one views the chart as continuous and level across the fold; the title page and the short introduction resting as a negligible thickness under the upper half of the chart. When closed the chart may have a place in the laboratory desk, or on the table; but if open, the "volume" may be framed and hung on the wall, so as to display the chart only.

On the chart we find the five scales that are now important: Delisle, Fahrenheit, Reamur, Centigrade and Absolute. At the foot of each scale will be found data for conversion into any one of the remaining scales. As regards range, the chart extends from -273°C. to $+228^{\circ}\text{C.}$, and there is obviously no advantage in carrying the scale higher, as modified figures may be read to the upper lines.

Mr. Marks gives us a much needed addition to laboratory resources, especially in relation to the Delisle scale and the early reversed aspect of the Centigrade scale, mentioned in the introduction; thus eliminating some of the troubles experienced by those reading certain old books.

GENERAL NOTES.

GOLDSMITHS HALL.—A meeting will be held at Goldsmiths Hall, London, at 8.30 p.m., on Wednesday, November 23rd, to discuss the problem of Modern Silverwork, with special reference to the Schemes of the Worshipful Company of Goldsmiths for improvement of design and craftsmanship. The production of work which in style and tendency will represent the artistic outlook of the present day, and the exhibition of such work to the public, will form the subject of debate. Sir Lawrence Weaver, K.B.E., will be in the chair, and the speakers will include Sir Hubert Llewellyn Smith, G.C.B., representatives of prominent trade firms, including Messrs. Elkington & Company, Limited, and the Goldsmiths and Silver-smiths Company, Limited, and Artist Craftsmen. Some examples of Modern Silverwork, lent for the occasion, will be exhibited after the meeting. Admission will be free by ticket on application before the 21st November to the Clerk of the Goldsmiths Company, Goldsmiths Hall, Foster Lane, E.C.2.

THE U.S.A. NATIONAL BUREAU OF ECONOMIC RESEARCH.—The National Bureau of Economic Research, 474, West 24th Street, New York, which was established in 1921 with the aid of grants from the Commonwealth Fund and the Carnegie Corporation to carry out expert investigations into economic questions, has published a number of important volumes, some of which—such as the reports on “Business Cycles and Unemployment and Employment Hours, and Earnings in Prosperity and Depression,” and “The Growth of American Trade Unions, 1880–1923”—may be studied with advantage by business men and others interested in similar problems on this side of the Atlantic.

The Bureau is now conducting an investigation into the output per hour of labour and the variations in output during the past three decades. American business firms who have any records at their disposal which would throw light on this question are requested to communicate with Professor Henry Jerome, 313, Sterling Hall, University of Wisconsin, Madison, Wisconsin.

LOUGHBOROUGH COLLEGE: OPEN SCHOLARSHIPS IN ENGINEERING.—The Governors of Loughborough College invite applications for the award of five open scholarships in the Faculty of Engineering, each of the annual value of £75, and tenable at the College for the period of the full Diploma Course. The scholarships are open to British subjects, not less than sixteen years of age, on October 1st, 1928, in any part of the Empire, and will be awarded upon the results of an examination held on April 24th–26th, 1928. Candidates resident in Great Britain and Ireland will be required to attend for examination at Loughborough. Candidates resident in other parts of the Empire will be examined on the same dates at approved Local Centres where recognised facilities are available.

Further particulars and application forms may be obtained from the Registrar, Loughborough College, Leicestershire, England.

THE INTERNATIONAL EXHIBITION OF INVENTIONS.—Organised and managed by the Institute of Patentees, 39, Victoria Street, London, S.W.1, the third international exhibition of inventions was held in the Central Hall, Westminster, the opening taking place on Wednesday, 12th October, and the closing on Saturday, 22nd October. Everyone is aware that mechanical appliances have enhanced enormously the productive power of human labour, but few people realise how gradual has been the process by which the power-driven machinery used at the present day was developed. No human brain, for instance, could have devised the cotton-spinning self-actor mule, as it is to-day, but ingenious inventors have added on to Samuel

Crompton's original machine one improvement after another, till now it is one of the marvels of mechanical ingenuity. In an exhibition such as that recently shown in Westminster Central Hall, the wellsprings of industrial progress are revealed. Here were to be seen improvements devised for domestic and household labour-saving appliances, agricultural implements, machine tools, steam engines, motor vehicles, and numerous varieties of plant and machinery both small and large. Aids for the housewife in the shape of improved kitchen equipment, such as egg whisks, cookers, saucepans, and dishes, or store-room and wardrobe contrivances of one kind and another, appeared in attractive array. On the other hand, the widespread use of private motor cars was indicated by the numerous exhibits of inventions designed to enable the car user to manage the garaging and execute lesser repairs for himself, or, as often happens, herself. In the section for mechanical devices and internal combustion engines, however, the engineer in search of fresh ideas was more likely to reap a harvest. Valve gears, steam turbines, pumps, lubricating appliances, cross-roads signalling apparatus, direction indicators, motor engines, each one claiming to be an advance on anything at present in regular use, were displayed. Too frequently exhibitions of that kind are attended mainly by amateurs who make a hobby of invention or engineering students interested in mechanics, and the larger public fail to take advantage of what is actually a great educational agency. During recent years, however, an improvement in that respect has been observable, and the latest exhibition was well designed to attract popular interest.

THE LIBRARY.

The following books have been presented to the Library since the last announcement:—

- Anderson, William J., A.R.I.B.A. The Architecture of the Renaissance in Italy. Fifth Edition revised by Arthur Stratton, F.S.A., F.R.I.B.A. London: B. T. Batsford Ltd., 1927.
- Barker, Prof. Aldred F., M.Sc. The Prospective Development of Peru as a Sheep-breeding and Wool-growing country. Leeds. 1927.
- Benny, L. B., M.A. Mathematics for students of Technology. Senior Course. Part I. London: Oxford University Press (Humphrey Milford). 1927.
- Blake, Ernest G. The prevention of dampness and condensation by the "Knapen" systems. London: C. Tinling & Co., Ltd. 1927.
- Bose, Sir Jagadis Chunder, F.R.S. 1. Collected Physical Papers. 2. Plant Autographs and their Revelations. London: Longmans, Green & Co., Ltd. 1927.
- Budden, Charles W., M.A., M.D. English Gothic Churches. London: B. T. Batsford, Ltd. 1927.
- Chancellor, E. Beresford. Disappearing London. "The Studio," Ltd. London. 1927.
- Crew, Albert. The Conduct of and Procedure at Public and Company Meetings. Ninth Edition. London: Jordan & Sons, Ltd. 1927.
- Davis, A. H., D.Sc. and G. W. C. Kaye, O.B.E., M.A., D.Sc. The Acoustics of Buildings. London: G. Bell & Sons, Ltd. 1927.
- Desaint, A. Ideas and Studies in Stencilling and Decorating. London: Charles Griffin & Co., Ltd. 1927.
- Domville-Fife, C. W. Savage Life in the Black Sudan. London: Seeley, Service & Co., Ltd. 1927.
- Everest, Arthur Ernest, D.Sc., Ph.D., F.I.C. The Higher Coal-Tar Hydrocarbons. London: Longmans, Green & Co., Ltd. 1927.
- Fairchild, Prof. Henry Pratt. The Foundations of Social Life. London: Chapman & Hall, Ltd. 1927.

- Glass, Frederick J. Drawing, Design and Craft-work. Second Edition. London: B. T. Batsford, Ltd. 1927.
- Gregory, Prof. T.E. and Dr. Hugh Dalton, M.P. London Essays in Economics: in honour of Edwin Cannan. London: George Routledge & Sons., Ltd. 1927.
- Halse, George W., B.Sc. Oil and Retortable Materials. London: Charles Griffin & Co., Ltd., 1927.
- Harrison, H. H. The Elements of Telephone Transmission. London: Longmans, Green & Co., Ltd. 1927.
- Hartley, Dorothy and Margaret M. Elliot, B.A. Life and Work of the People of England. London: B. T. Batsford, Ltd. 1925.
- Ince, E. L. Ordinary differential Equations. London: Longmans, Green & Co., Ltd. 1927.
- Jekyll, Gertrude, Old English Household Life: B. T. Batsford, Ltd. 1925.
- Jones, Sydney R. Touring England. London: B. T. Batsford, Ltd. 1927.
- Knights, Charles C., and Frank E. Norman. Commercial Art Practice. London: Crosby Lockwood & Son. 1927.
- MacConnell, C. J. Dunbar. A Complete Manual of the Spanish Language. London: Effingham Wilson. 1927.
- Macconochie, Arthur F., B.Sc. Thermodynamics Applied to Engineering. London: Longmans, Green & Co., Ltd. 1927.
- McDowall, R. J. S., D.Sc., M.B. The Mind. A series of Lectures delivered at King's College, London, in 1927, by various Professors. Edited by Dr. McDowall. London: Longmans, Green & Co., Ltd. 1927.
- Marks, Percy L. Thermometric Conversion Chart. London: Crosby Lockwood & Son. 1927.
- Mehta, N. B., Ph.D. Indian Railways: Rates and Regulations. London: P. S. King & Son, Ltd. 1927.
- Mitchell, S. A., Ph.D., LL.D. and C. G. Abbot, M.S., D.Sc. The Fundamentals of Astronomy. London: Chapman & Hall, Ltd. 1927.
- Neave, Frederick George, LL.D. A Handbook of Commercial Law. Third Edition. London: Effingham Wilson. 1927.
- Neblette, C. B. Photography—its Principles and Practice. London: Chapman & Hall, Ltd. 1927.
- Page, Calvin Samuel. The Atomic Science. Chicago: Science Publishing Company. 1927.
- Pulbrook, Ernest C. English Country Life and Work. London: B. T. Batsford, Ltd. 1922.
- Rutnagur, S. M., J.P. Bombay Industries: The Cotton Mills, Bombay: The Indian Textile Journal Ltd. 1927.
- Saunders, Vivian T., M.A. The Polarimeter. London: Adam Hilger, Ltd. 1927.
- Statham, H. Heathcote. A Short Critical History of Architecture. Second Edition. Edited by G. Maxwell Aylwin, F.R.I.B.A. London: B. T. Batsford, Ltd. 1927.
- Stewart, Alfred W., D.Sc. Recent Advances in Organic Chemistry. Fifth Edition. Two Vols. London: Longmans, Green & Co., Ltd. 1927.
- Stewart, J. F. Manual of Forest Engineering and Extraction. London: Chapman & Hall, Ltd. 1927.
- Turner, D. M., M.A., B.Sc. History of Science Teaching in England. London: Chapman & Hall, Ltd. 1927.
- Twyman, F., F.R.S. Two lectures on the development and Present Position of Chemical Analysis by emission Spectra. London: Adam Hilger Ltd. 1927.
- Wakefield, Sir Charles Cheers, Bt. On Leaving School. London: Hodder & Stoughton. 1927.
- Weir, John W., M.D. Comets and the Sun. London: Longmans, Green & Co., Ltd. 1927.
- Williamson, J. W., B.Sc. In a Persian Oil Field. London: Ernest Benn, Ltd. 1927.

MEETINGS OF THE SOCIETY.

:O:

ORDINARY MEETINGS.

Wednesday evenings at 8 o'clock (unless otherwise announced).

NOVEMBER 23.—T. HEDLEY BARRY, "Malayan Varnish Resins." A. F. SUTER, Esq., will preside.

NOVEMBER 30.—PROFESSOR HENRY F. ARMSTRONG, LL.D., Ph.D., F.R.S., "Marcellin Berthelot and Synthetic Chemistry." HIS EXCELLENCY THE FRENCH AMBASSADOR will preside.

DECEMBER 7.—S. J. DULY, M.A., Head of Department of Commercial Products, City of London College, Mitchell Student for 1925-6. "The Damage to Cargo due to 'Ship's Sweat.'"

DECEMBER 14.—MAJOR RAYMOND G. H. CLEMENTS, M.C., M.Inst.C.E., "The Evolution of Modern Road Surfaces." SIR FRANK BAINES, C.V.O., C.B.E., will preside.

JANUARY 18.—ARTHUR HENRY BARKER, B.Sc., B.A., M.I.E.E., Wh.Sch., "Methods of Radiant Heating." PROFESSOR A. E. RICHARDSON, F.R.I.B.A., Professor of Architecture, University College, London, will preside.

JANUARY 25.—H. DE KONINGH, "Enamels."

FEBRUARY 1.—CHARLES HERBERT WRIGHT, B.A., "Modern Aspects of Rubber Cultivation." SIR DAVID PRAIN, C.M.G., C.I.E., M.B., LL.D., F.R.S., will preside.

FEBRUARY 8.—HENRY D. WILKINSON, M.I.E.E., "Theatre Lighting."

FEBRUARY 15.—CAPTAIN SIR BEACHCROFT TOWSE, V.C., K.C.V.O., C.B.E., "The Education of the Blind."

FEBRUARY 22.—H. R. H. HALL, M.V.O., M.A., D.Litt., F.S.A., F.B.M., Keeper of the Department of Egyptian and Assyrian Antiquities, British Museum, "Recent Discoveries at Ur."

FEBRUARY 29.—ARCHIBALD CRAWFORD, K.C., Director of the Economic League, "Industry Fifty Years Hence." THE RT. HON. G. N. BARNES, P.C., C.H., will preside.

MARCH 7.—J. H. JEANS, D.Sc., F.R.S., Secretary of the Royal Society, "Some Wider Problems of Cosmogony." (Trueman Wood Lecture).

MARCH 14.—HAROLD G. BROWN, of the D.P. Battery Co., Ltd., "Lead Storage Batteries."

APRIL 18.—ALFRED C. BOSSOM, F.R.I.B.A., "American Architecture."

Dates to be hereafter announced :—

ERNEST P. A. LAW, C.B., C.V.O., "Hampton Court Palace, its Architecture and Preservation."

CAPTAIN SIR ARTHUR CLARKE, K.B.E., "Trinity House: its History and its Work."

CAPTAIN ROBERT E. LLOYD-OWEN, M.C., A.M.I.E.E., "Loud-Speaker Characteristics."

INDIAN SECTION.

Friday afternoons, at 4.30 o'clock.

DECEMBER 9.—SIR DAVID T. CHADWICK, C.S.I., C.I.E., "The Indian Tariff Board." SIR CAMPBELL RHODES, C.B.E., will preside.

JANUARY 20.—MAURICE G. SIMPSON, M.I.E.E., Director-in-Chief, Indo-European Telegraph Department, "The Indo-European Telegraph Department." SIR RAYNER C. BARKER, C.I.E., will preside.

FEBRUARY 10.—SIR EDWARD A. GAIT, K.C.S.I., C.I.E., "Ancient Bihar and Orissa." (Sir George Birdwood Memorial Lecture). THE RT. HON. VISCOUNT CHELMSFORD, G.M.S.I., G.C.M.G., G.M.I.E., G.B.E., will preside.

Date to be hereafter announced :—

SIR JAMES MACKENNA, C.I.E., "The Sugar Industry in India, Java and Mauritius."

DOMINIONS AND COLONIES SECTION.

MONDAY, NOVEMBER 28.—H. E. THE MARQUIS DE MERRY DEL VAL, G.C.V.O., LL.D., will deliver a short explanatory lecture on a film showing the visit of T.M. the King and Queen of Spain to the Djebala and Rif Country of Morocco.

TUESDAY, JANUARY 31.—THE RIGHT HON. LORD LOVAT, K.T., K.C.M.G., K.C.V.O., C.B., D.S.O., "Migration in the Empire." THE RIGHT HON. THE EARL OF CLARENDON will preside.

TUESDAY, MAY 22.—CAPTAIN SIR CECIL ARMITAGE, K.B.E., C.M.G., D.S.O., "Gambia" (illustrated by lantern slides).

Date to be hereafter announced :—

COL. H. W. CROSTHWAITE, C.I.E., C.M.G., R.E., "Aerial Photography as applied to Survey."

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

PROFESSOR H. C. H. CARPENTER, M.A., A.R.S.M., F.R.S., "Alloy Steels, their Manufacture, Properties, and Uses." Four Lectures. November 14, 21, 28, and December 5.

For Syllabus see *Journal* dated October 28.

ALBERT ERNEST DUNSTAN, D.Sc., F.I.C., F.C.S., "The Scientific Foundation of the Refining of Petroleum." Three lectures. January 16, 23, and 30.

LECTURE I.—Retrospect. Sir Boverton Redwood's Cantor Lectures in 1886 Chemical and Physical Nature of Petroleum. Natural Gas and its treatment. Methods of Distillation.

LECTURE II.—The Refining of motor gasoline ; of special spirits and of kerosene ; of waxes and of lubricating oils.

LECTURE III.—Cracking and the refining of cracked gasoline. Synthetic chemistry of petroleum.

H. GOUGH, "Fatigue Phenomena, with special reference to Single Crystals." Three lectures. February 13, 20, and 27.

A. G. HUNTLEY, May Construction Company, Ltd., "Acoustics." Three lectures. April 16, 23 and 30.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, NOVEMBER 21.—Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Sir Herbert Baker, A.R.A., "The Government Offices of Pretoria and the New Delhi."
Academy of Arts, Royal Burlington House, W. 4 p.m. Dr. A. P. Laurie, "Modern Pigments: their proper Selection and Use."
British Academy, at Burlington House, W. 5 p.m. Mr. S. Casson, "Excavations in the Hippodrome at Constantinople."
Electrical Engineers, Institution of, Savoy Place, W.C. 7 p.m. Mr. W. Day, "Automatic Telephony," at the University, Liverpool. 7 p.m.

Geographical Society, at Aeolian Hall, 135, New Bond Street, W. 8.30 p.m. Major R. E. Cheesman, "The Blue Nile."

Mechanical Engineers, Institution of, Storey's Gate, S.W. 6.30 p.m. Mr. G. K. Wood, "The Locomotive Boiler in Service."

North East Coast Institution of Engineers and Shipbuilders, at Cleveland Scientific and Technical Institution, Middlesbrough. 7.30 p.m. Mr. R. F. Battey, "The Progress in Diesel Design."

Philologie, Sciences et Beaux Arts, Société Internationale de, 8, Taviton Street, W.C. 3.30 p.m. Rev. Louis Rabinowitz, "The Maccabees."

Science Guild, British, at Goldsmiths' Hall, Foster Lane, E.C. 4 p.m. The Very Rev. Dean Inge, "Scientific Ethics." (Norman Lockyer Lecture).

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Prince D. Svyatopolk Mirsky, "The Russian Novel, 1845-1880." (Lecture VII).
At King's College, Strand, W.C. 5.30 p.m. Rev. C. F. Rogers, "Ecclesiastical Music." (Lecture II).

TUESDAY, NOVEMBER 22. Academy of Arts, Royal, Burlington House, W. 4 p.m. Dr. A. P. Laurie, "Methods of Wall Painting."
Anthropological Institute, 52, Upper Bedford Place, W.C. 8.30 p.m. The Misses French, "Where the Great Wall Ends."

Automobile Engineers, Institution of, at the Institution of Electrical Engineers, Savoy Place, W.C. 8 p.m. Captain C. H. Kuhne, "Military Transport Vehicles—Recent Development and their Commercial Significance." (Joint Meeting with the Institute of Transport).

Chadwick Public Lecture, at the Royal Society of Arts, Adelphi, W.C. 8.15 p.m. Major Harry Barnes, "Housing 1885 to 1927."

Illuminating Engineering Society, at the E.L.M.A. Lighting Service Bureau, 55, Savoy Street, W.C. 7 p.m. Opening Meeting and Report of Committee on Progress in Electric Lamps and Lighting Appliances.
Opticians, British Practical, at 8, Tavistock Street, W.C. 8.15 p.m. Dr. C. H. Betts, "Illusions."

Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. F. G. Newmarch, "Some of my Experiences in Colour Work."

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Sir William Bragg, "A Year's Work in X-Ray-Crystal Analysis."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Sir Bernard Pares, "Russian History to 1861." (Lecture VII).
At King's College, Strand, W.C. 5.30 p.m. Miss Hilda D. Oakeley, "The Philosophy of Personality." (Lecture II).

WEDNESDAY, NOVEMBER 23. Academy of Arts, Royal, Burlington House, W. 4 p.m. Dr. A. P. Laurie, "Recent Researches on the Preservation of Ancient Buildings and Stone Decay."

Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Mr. Martin S. Briggs, "The Architect." (Informal lecture on Architecture for Workers in the Building Trades).

Automobile Engineers, Institution of, at the Engineers' Club, Albert Square, Manchester. 7 p.m. Mr. H. B. Taylor, "High-Speed Compression Ignition Engine Research."

At the Institution of Mechanical Engineers, Storey's Gate, S.W. 7.45 p.m. Mr. H. L. Horning, "The Trend of Design in Motor Trucks and Motor Coaches for Fleet Operation."

Faraday Society, at Burlington House, W. 2.30 p.m. and 5.15 p.m. General Discussion on "Cohesion and Related Problems." Introductory Survey by Prof. Dr. C. H. Desch, and papers by Messrs. N. K. Adam, H. J. Gough, and A. A. Griffith, Prof. B. P. Haigh, Sir W. B. Hardy, Professors A. Joffé, J. E. Lennard, M. Polanti, A. W. Porter, G. Sachs, G. I. Taylor, and Messrs. F. I. G. Rawlins and A. M. Taylor.

Fuel, Institute of, at the Institution of Electrical Engineers, Savoy Place, W.C. 10.30 a.m., and 2.30 p.m. Rt. Hon. Sir Alfred Mond, Presidential Address. Sir Philip Dawson, "National Electricity Supply—Better Utilisation of our Fuel Resources." Mr. J. Anderson, "Operating Experience of Steam Production at 5,300 lbs. Pressure." Messrs. T. Nordenson and H. C. Armstrong, "Measurement of Steam Flow in Works Practice." Mr. P. H. N. Ulander, "Preheated Air for Boiler Furnaces."

Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Dr. A. Dingwall Fordyce, "The Prevention of Heart Disease."

Whitechapel Art Gallery, Aldgate, E. 7 p.m. Mr. M. J. Hanc, "Czechoslovakia—Fine Arts."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. Otakar Voadlo, "English and American Influences in Czech Literature." (Lecture III).

At King's College, Strand, W.C. 5.30 p.m. The Very Rev. the Dean of Salisbury, "The Mystery Religions." (Lecture III).

5.30 p.m. Mr. E. Salter Davies, "Secondary Education (4) Technical Institutes, Evening Schools and Day Continuation Schools."

At the London School of Economics, Houghton Street, Aldwych, W.C. 6 p.m. Mr. H. Coleman, "The Numeralalpha Filing System and the Ronodex Visible Index System."

At University College, Gower Street, W.C. 3 p.m. Dr. C. Pellizzi, "Dante in alcuni giudizi contemporanei." (in Italian). (Lecture IV).

5.30 p.m. Mr. C. O. G. Douie, "The Report of the Departmental Committee on Libraries."

5.30 p.m. Mr. I. C. Gröndahl, "Regions and Place-Names in Norway." (Lecture III).

THURSDAY, NOVEMBER 24. Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m.

Chemical Society, Burlington House, W. 8 p.m. Prof. Dr. W. A. Bone, "Gaseous Combustion at High Pressures."

Fuel, Institute of, at the Institution of Electrical Engineers, Savoy Place, W.C. 10 a.m., and 2.30 p.m. Mr. Robert Ray, "The British Coking Industry and Some of its Products." N. J. Bowater, "Vertical Intermittent Chamber Ovens." Professor M. W. Travers, "The Chemical Study of Processes Involving the Carbonisation of Coal by Internal Heating." Messrs. J. Ivon Graham and D. G. Skinner, "Conversion of Coal into Oil by the Bergius Process." Dr. A. E. Dunstan, and Dr. H. G. Shatwell, "Liquid Fuels, Other than Petroleum." Professor M. W. Travers, F.R.S., "A Critical Study of the Determination of Heats of Formation of Steam and of Carbon Dioxide."

L.C.C., The Geffrve Museum, Kingsland Road, Shoreditch, E. 7.30 p.m. Prof. J. R. Ainsworth Davis, "Australian Timbers."

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Dr. R. E. M. Wheeler, "London before the Norman Conquest." (Lecture II).

Wireless Technology, Institute of, at the Engineers' Club, Coventry Street, W. 7 p.m. Mr. W. H. B. de M. Leathes, "Ultra Short Waves."

University of London, at Bedford College for Women, Regents Park, N.W. 4.15 p.m. Prof. Eccles, "Voltaire: les meilleurs moments et les plus belles pages." (Lecture VII).

At Imperial College of Science, South Kensington, S.W. 5.15 p.m. Mr. R. H. Fowler, "Statistical Mechanics, Old and New." (Lecture II).

At King's College, Strand, W.C. 5.15 p.m. Miss A. E. Levett, "Daniel Defoe."

5.30 p.m. Mr. Martin Shaw, "Good and Bad Hymns." 5.30 p.m. Mr. Ifor L. Evans, "Peasant Proprietorship in South-Eastern Europe." (Lecture V).

At the London School of Economics, Houghton Street, Aldwych, W.C. 5.30 p.m. Dr. C. Grant Robertson, "History and Citizenship."

At University College, Gower Street, W.C. 5.15 p.m. Prof. de Montmorency, "Customary Law in the British Empire." (Lecture IV).

5.30 p.m. Air-Marshal Sir John Maitland Salmond, "The Air Force in Home Defence."

5.30 p.m. Miss E. Jeffries Davis, "London Place-Names." (Lecture III).

At the Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Mr. J. P. Blake, "The History of the Bedstead."

FRIDAY, NOVEMBER 25. Engineering Inspection, Institution of, at the Royal Society of Arts, Adelphi, W.C. 7.30 p.m. Mr. Leonard Andrews, "Elutriation as an Aid to Engineering Inspection."

Philologie, Sciences et Beaux Arts, Société Internationale de, 8, Tavistock Street, W.C. 8.15 p.m. Rev. E. H. Vicars, "Shakespeare's 'Tempest'."

Physical Society, at the Imperial College of Science and Technology, South Kensington, S.W. 5 p.m. (1) Mr. A. E. Knowler, "The Electrical Resistance of Porous Materials"; (2) Mr. P. K. Kichlu, "Regularities in the Spectrum of Ionised Neon"; (3) Dr. Ezer Griffiths, "A Calorimeter for the Determination of the Heat developed by Fruit."

Psychology, National Institute of Industrial, at the Royal Society of Arts, Adelphi, W.C. 7.30 p.m.

University of London, at King's College, Strand, W.C. 5.30 p.m. Mr. C. J. Gadd, "The Beginnings of the City of Ur."

SATURDAY, NOVEMBER 26. L.C.C., The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Mr. John E. S. Dallas, "Nature in the Alps."

Royal Institution, 21, Albemarle Street, W. 3 p.m. Mr. Gustav Holst, "Samuel Wesley and Robert Pearsall." (Lecture II).

JOURNAL OF THE ROYAL SOCIETY OF ARTS

No. 3914.

VOL. LXXVI.

FRIDAY, NOVEMBER 25th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK,

MONDAY, NOVEMBER 28th, at 4.30 p.m. (Dominions and Colonies Section). H.E. THE SPANISH AMBASSADOR, THE MARQUIS DE MERRY DEL VAL, G.C.V.O., LL.D., will deliver a short explanatory lecture on a film showing the visit of T.M. The King and Queen of Spain to the Djebala and Riff Country of Morocco. THE RT. HON. SIR MAURICE DE BUNSEN, Bt., G.C.M.G., G.C.V.O., C.B., will preside.

Tea will be served in the library at 4 p.m. before the meeting.

MONDAY, NOVEMBER 28th, at 8 p.m. (Cantor Lecture.) PROFESSOR H. C. H. CARPENTER, M.A., A.R.S.M., F.R.S., "Alloy Steels, their Manufacture, Properties and Uses." (Lecture III.)

WEDNESDAY, NOVEMBER 30th, at 8 p.m. (Ordinary Meeting.) PROFESSOR HENRY E. ARMSTRONG, LL.D., Ph.D., F.R.S., "Marcellin Berthelot and Synthetic Chemistry." H.E. THE FRENCH AMBASSADOR, M. DE FLEURIAU, G.C.V.O., COMMANDEUR LÉGION D'HONNEUR, will preside.

COUNCIL.

A meeting of the Council was held on Monday, November 14th. Present :— Sir Philip Magnus, Bt., in the Chair ; Sir Charles H. Armstrong ; Mr. Llewelyn B. Atkinson, M.I.E.E. ; Rt. Hon. George N. Barnes, C.H. ; Sir Charles Stuart Bayley, G.C.I.E., K.C.S.I. ; Captain Sir Arthur Clarke, K.B.E. ; Sir William Henry Davison, K.B.E., D.L., M.P. ; Rear-Admiral James de Courcy Hamilton, M.V.O. ; Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S. ; Major Sir Humphrey Leggett, R.E., D.S.O. ; Sir Reginald A. Mant, K.C.I.E., C.S.I. ; Col. The Master of Sempill ; Mr. J. Swinburne, F.R.S. ; Sir George

Sutton, Bt., and Mr. Carmichael Thomas, with Mr. G. K. Menzies, M.A. (Secretary), and Mr. William Perry, B.A. (Assistant-Secretary).

Sir Alfred Yarrow, Bt., F.R.S., was elected a Vice-President of the Society and Member of the Council in place of Sir Allan Garrett Anderson, K.B.E., who was unable to serve.

It was reported that a meeting in connexion with the preservation of the three Thomas à Becket Cottages at West Tarring had been held at Worthing, the Mayor being in the Chair, and that a public subscription had been inaugurated to raise £1,000 with the object of permanently saving the cottages, which had been handed over to the Sussex Archæological Trust.

The Council's reply to the Questionnaire of the Departmental Committee on Examinations for Part-time Students was finally approved.

Mr. A. Kahn, H.M.I.S., was elected a Life Fellow of the Society, under the terms of Bye-Law 53.

The following candidates were duly elected Fellows of the Society :—

Amies, Arthur Pilgrim, J.P., Adelaide, South Australia.

Atthoe, Major George Benfield Jones, London.

Attar, N. S. Pattabhirama, Ayyampet, Tanjore, India.

Buckley, Cornelius Francis, Valletta, Malta.

Ertz, Edward Frederick, Pulborough, Sussex.

Field, Frank James, Buxton, Derbyshire.

Gill, John Blackmore, Chelmsford, Essex.

Greaves, Sir Ewart, Horsham, Sussex.

Jackson, B. R., London.

Kanojie, Jagdish Narain, Delhi, India.

McKerrow, James Clark, M.B., Ch.B., London.

Mason, Arthur James, London.

Rupchand, Bhagwardas, Bombay, India.

Rye, Reginald A., London.

Singhal, Jwala Prasad, M.A., LL.B., Indore, India.

Slater, Bertie, Kippax, near Leeds.

Srivastawa, Professor Badri Pershad, Naya Bazar, Gwalior, India.

Stieger, H. J., D.I.C., London.

Western Australia, The University of, Perth, Australia.

Williams, Ernest Jones, London.

Yates, Lieut.-Colonel H. I. F., London.

Sir Herbert Jackson, K.B.E., F.R.S., was invited to represent the Society at the Jubilee Celebration of the Institute of Chemistry in December next.

The arrangements for the forthcoming session were further considered.

Other formal and financial business was transacted.

THIRD ORDINARY MEETING.

WEDNESDAY, NOVEMBER 16th, 1927. THE RT. HON. LORD DAWSON OF PENN, G.C.V.O., K.C.B., K.C.M.G., M.D., D.C.L., in the Chair.

A paper on "Overcrowding in Public Conveyances," was read by PROFESSOR LEONARD HILL, M.B., F.R.S., Hon.A.R.I.B.A. The paper and discussion will be published in the *Journal* dated December 9th.

CANTOR LECTURES.

MONDAY, NOVEMBER 21st, 1927. PROFESSOR H. C. H. CARPENTER, M.A., A.R.S.M., F.R.S., Professor of Metallurgy, Imperial College of Science and Technology, delivered the second of his course of four lectures on "Alloy Steels, their Manufacture, Properties, and Uses."

The lectures will be published in the *Journal* during the Christmas recess.

REPRINT OF CANTOR LECTURES.

Reprints of the following Cantor Lectures delivered during last session are now available in pamphlet form and can be obtained from the Secretary, Royal Society of Arts, John Street, Adelphi, W.C.2 :—

"Recent Progress in Optics." Three Lectures. By L. C. Martin, D.Sc., A.R.C.S. Price 2s.

"Photo-elastic Measurements of Stress Distribution." By Professor E. G. Coker, M.A., D.Sc., F.R.S., M.Inst.C.E. Price 2s.

"Some Industrial Applications of Electrothermics." By G. I. Finch, M.B.E. Price 2s. 6d.

"The Measurement of Light." By John W. T. Walsh, M.A., D.Sc., F.Inst.P. Price 2s.

A complete list of Cantor, Howard and other lectures which have been published separately in pamphlet form and are still available can also be had on application.

PROCEEDINGS OF THE SOCIETY.

SECOND ORDINARY MEETING.

WEDNESDAY, NOVEMBER 9TH, 1927.

THE HON. SIR ARTHUR STANLEY, G.B.E., C.B., M.V.O., LL.D., Chairman,
Royal Automobile Club, in the Chair.

THE CHAIRMAN remarked that he had been told it was his duty to introduce the lecturer, but to introduce Colonel Mervyn O'Gorman to anybody who was connected in any way with motoring was absolutely unnecessary. From the very early days of motoring Colonel O'Gorman had been one of the most prominent members of the Royal Automobile Club, and he had been one of the foremost men in dealing with every aspect of the problem of road traffic. In all international traffic questions

Colonel O'Gorman had always represented this country, and, what was more, had been able to expound the various sides of the matter, as most Englishmen could not do, in extremely fluent French. If Colonel O'Gorman had been allowed to address the present meeting in French he (the Chairman) was perfectly sure that he would carry the whole of his audience with him, as he had done when he had represented the Royal Automobile Club on the International Body. It was no exaggeration to say that in all international matters where agreement had been arrived at between the various countries, that happy outcome had been largely due to the tact and skill which Colonel O'Gorman had displayed at the meetings which he had attended.

The following paper was then read :—

ROAD TRAFFIC PROBLEMS OF THE PEDESTRIAN.

By MERVYN O'GORMAN, C.B., D.Sc., M.Inst.C.E.

Before reading my paper I ask permission to make a few preliminary remarks.

The object I have in view is to save life and limb. The method I propose is to introduce an element of graciousness into the chance relations of all traffic units, pedestrian or other. You, sir, as Treasurer of one of London's greatest hospitals and the devoted Chairman of the Red Cross and St. John's Ambulance Society, will, I think, join in my wishes whether or not you are critical of the method, and you will agree that the matter is urgent.

The method consists in the adoption of certain customs, and I recognise that it is vain for an individual or Government to propose customs, however beneficial, or impose laws however sagacious, *unless* those who are asked to conform can see good reason for compliance (witness the disobedience to the 20-mile limit here, and prohibition of alcohol elsewhere).

Not only so, but people desire, before they will endorse the view that some mode of conduct is economic, to foresee that the advantage is

- (a) due to appear pretty soon.
- (b) certain.
- (c) and lastly, cheap to get.

As regards (a) in modern life, most economic operations have a time cycle, longer than the one-year cycle which includes sowing and harvest. The length of delay that can be tolerated depends on temperament and education (e.g., the British public faced deflation with its long and painful cycle more readily than the rest of Europe).

As regards (b) the British are handicapped by a leaning almost amounting to a preference for truth. To insist on certainty is the same thing as to refuse to make experiment since experiment is not experiment if the result is certain, yet economic knowledge is mostly got by thought out of experiment. I say the British are handicapped because the ostensible method of achieving experiment is to practice the deception of declaring its results to be certain. This we would do reluctantly. There is another plan, perhaps Britishers can rise to it, and

I have tried it herein, viz., to suggest that, win or lose, the experiment is worth the knowledge that must certainly accrue from a sustained trial.

As to (c), fortunately the capital cost of the proposals is almost nil.

Lastly, these proposals for "footway saving" escape the condemnation that fell on Willett's "daylight saving," namely, that of being novel (the term of opprobrium is, I believe, "new fangled.") This is almost their third appearance. "What I say 3 times is true."

Road Traffic Problems being related to street accidents may well give pause to the man in the street. To him they are of three sorts.

- (a). The insoluble—like putting a quart into a pint pot.
- (b). Those of costly solution—by knocking down houses.
- (c). Those of imperative solution—like preventing others from knocking him down.

When he has intelligently dismissed the insoluble from his mind, when, as a rate and tax payer he has buttoned his pocket against any more of the costly, then, as a pedestrian he has often, in the past at least, used his predominant vote to thwart any traffic (other than his own category) that hurts him. Thus after spending much on roads, he has until lately plumped for the cheap and the obvious in legislation for his bare safety.

The accidents for 1926 in Greater London have shown him 47,000 times that he has not got safety thereby. In relation to the increase of traffic, the increase of accidents is three times worse in six years. Why? Perhaps the problem of the motor car is so recent that he has not applied to its regulation and legislation the horse sense he uses in other walks of life, where he has long learnt that the remedy which seems obvious is often wrong. Just as a child's tears may commonly be better cured by a disagreeable dose of oil than by the obvious handkerchief or the easy toffee.

TRAFFIC FLOW.

He is disconcerted because the traffic trouble has increased more than the traffic flow* and the ill is too deep-seated for cure by the cheap and easy police trap, the general speed limit and the local speed limits. Why not abandon this and try the dose of oil, that is, foster a freer movement? Instead of thwarting and blocking motor traffic by act, by vote, by decree, by notice boards, by sharp pavement corners, central road standards, wrongly placed refuges, lavatories, tram lines, and by police regulations, look for another policy—and that not a policy of clearances, widenings and destruction of values. There is one at hand, astonishing in its novelty: Discover the conditions for maximum flow and insist on them. Help the traffic to flow to its objective. Speed the walker to his destination.

*The traffic flow has increased 38 per cent., but the fatalities 55 per cent., since 1920 in Greater London 1926.

If such proposals sound perilous to some people and fatuous to others, an all-round examination should show them up. How, for example, would this suggestion affect that most-to-be-considered and most fragile traffic unit, the pedestrian? In the order of their importance, two things impeded the pedestrian :

- (a) The other pedestrians.
- (b) The vehicles.

There is no doubt he could get home easily and swiftly if the others on the pavement kept to their own side, did not stop or swerve abruptly without notice, did not walk several abreast at a pace below the normal, did not carry sticks and umbrellas broadside, or at eye level, did not link arms, lead dogs, push prams, and gossip in dawdling disregard of the tired and busy, or if they had regard to his need to pass when they pause before the shops, or if they did not force him dangerously into the roadway. I suggest considerateness in relation to (a). For (b) I submit as beyond refutation, that if two bodies of traffic utilise, however briefly, the same area to move upon, whether this area be a river, an ocean, the air, the roads or the railroads, if one traffic group is subject to one set of rules and customs, while the other obeys dissimilar rules and customs, or no rules at all, then crashes, complaints, casualties and disasters are not only likely—they are certain.

TO HELP THE FLOW CLEAR THE ROAD.

Reverting to (a) considerateness among pedestrians, if such universal considerateness were found to increase the walker's rate of progress by, say, one-third, it becomes a question whether the effort of being himself considerate would increase his fatigue in proportion. Might he not even lessen his fatigue? I say that he would lessen it; he would not increase his rate of walking; he would mainly diminish his amount of dawdling—for if the flow were increased 30%, the pavement crowding would be diminished by 30%, on the principle that each walker will cumber the way for one-third less time—and it is well known how much easier is the going on a clearer road. In fact, there is profit at compound interest for the considerate in addition to the satisfaction of having "played the game."

I have not begun in this way with pedestrian traffic to secure a point by verbal trickery, but to bring out the principle of considerateness; in the interests of which I will put the case more crudely.

HELP THE FLOW BY NOT BEING TOO GREEDY.

The walker is inconsiderate to his own and other traffic; he is greedy and forgets that greed defeats itself by choking. The capuchin ape in the presence of plenty will so pack his food in his mouth, his cheek pouches, in his hands, under his arm pits and under his seat, that he can neither eat, swallow, move or profit by the supply. Yet he is both clever and amusing; in view of this

may I be forgiven for saying that in him we have a model of the greedy pedestrian? Motor drivers are also greedy of the road, but their voluntary adoption of certain rules and customs of self restraint excuses them to that extent from conforming so completely to the type. They have evolved a trifle further!

Let us first see what form a walker's considerateness and carefulness should take, and thereafter decide how to make it widespread. As Sir H. Maybury's Committee said:—"People cannot be careful merely by trying to be careful—they must know how to be careful."

HELP THE FLOW BY OBEYING A CODE OF THE ROAD.

It is a common experience whose lesson is not denied that a disordered crowd of a hundred persons of which half wishes to advance and half to retreat down the same street, cannot attain to the freedom of movement of two marshalled groups of double the number moving, say, like soldiers. Nevertheless and paradoxically, each and several of us would rather be dead than move to the office in step with a phalanx of mixed clerks. We claim that *homo sapiens* is entitled to move to his office unintelligently and laboriously. I cannot refute this claim, but the lesson remains; ordered traffic is free and speedy; unregulated traffic is slow, dangerous, laborious and wasteful.

The question has now shifted to this: How to maintain the glamour of ostensible individual motility without losing our freedom to move? How to look like the Panjandrum without being hampered by his draperies? It is established that what mainly impedes traffic is the traffic itself, and that an impediment starts when two units aspire to the same piece of ground at the same time.

HELP THE FLOW BY SHOWING YOUR INTENTIONS.

If either knew in advance that the other was aiming for just that spot at that particular speed he would wish to change course, and on achieving that wish both would pass as easily as if the threat of obstruction had not arisen. The first step towards freedom is by self-help—not by policemen. It is for all traffic units, including pedestrians, to indicate in advance their intention; and be it said at once this does not mean that the walker is to be asked to use his hands like a motorist, and convert himself into an animated signal post or a spasmodic windmill. There are other means.

It is incontestible that "to show your intention" is necessary for free traffic flow, and this maxim is strengthened by recognising that it is an extension for land use of the "show your helm" which rules the sea. It is the underlying basis of all road customs which assist and make for safety in road transport. needs to be imported to the sidewalks.

HELP THE FLOW BY KEEPING YOUR OWN SIDE.

The first practical application of this maxim is for those units which are

travelling in one sense to show their intention of continuing in that direction by ranging themselves on the appropriate side of the pavement ; and as this cannot be done unless a selection is made between " keep to the left " and " keep to the right," I suggest taking the left to avoid any " nose on " meeting with another pedestrian on the same footway.

Thus the most important and most frequently needed of all signals of intention is given without the effort of moving the hand. If once this habit were established and general, it would no doubt be advisable when one is about to contravene it to make some positive sign with hand or head, but we are far from that stage at present.

HELP THE FLOW BY ALLOWING OVERTAKING.

If it is sensible that traffic units, *e.g.*, walkers should not block those coming towards them, who can see their faces and, perhaps, read their purpose to some extent, so also must they not retard those anxious to overtake from behind. Free overtaking is the only escape from condemning the whole stream to the speed of its slowest unit. Natural man has to make some special effort of self-restraint to yield place to one who overtakes him. The name of that effort is courtesy.

Luckily overtaking is unconsciously encouraged if each will keep as far as possible to his left in the available pavement space, and this solution alone would be fairly effective if the sidewalk were a walk only and not also a market. I allude to shop window gazing and the extra function of a market which the lure of the shop displays has imposed on the pavements.

HELP THE FLOW BY ORDERLY SHOP GAZING.

Where a pavement is not only a passage but also a market, a decision is needed to delimit by common consent the rights, *i.e.*, the " line of convenience " between the passers-by and the marketers—the shop gazers. The use of white lines on busy footways to allow the marketers a pre-determined share of the width as gazing ground may one day come. If intolerable at present, these permanent lines will, perhaps, commend themselves when the inconvenience of the present " bump and walk round " regime has become more acute. There is every prospect of this !

The discomfort is already so great that I see hope. Experience shows that the land must be hurt with the plough before it will yield the joys of a crop. The pedestrian is a toad under his own harrow. He has only got to lift it for he owns and drives his own harrow.

THE SPLASHING OF MUD

Greatly concerns his method of walking. The total amount of splashing received, on the average, by the walker on the footways at present, when everyone walks pell-mell is roughly to be measured by the average time duration

of the average wet weather walk. Under the "keep left" regime the average walk will occupy less time—to take a figure, say one-third less time. If so, for all crowded footways the total amount of splashed clothes should be less by about one-third.

During an indeterminate period of initiating the "keep left" regime it may be suggested that those who are loyal to it will receive most of the splashing when they walk on the right hand pavement. This is so, but it need not be so. He who wants to "keep left" and not be splashed *at all* could often plan that part of his walk which is not by his affairs tied to a particular pavement, so that he proceeds on the left side of the left-hand pavement. This is always the wall side, until the footway is full. When it is full the splashing is one-third less than with pell-mell walking. Such a division of walkers into two streams on two separate pavements in accord with their direction of travel is entirely advantageous to flow in all cases when the numbers are about equally divided, because overtaking is still favoured by the units keeping to their proper side.

The stratification then becomes :—

- (A) Nearest the wall or shops—those who walk slowest, or want to look at shops.
- (B) Outside these and overtaking them on their right—those who walk somewhat faster.
- (C) Outside these, those who travel faster still—and therefore those whose time of exposure to the splashing is least.

Broadly, therefore, the "keep left" habit appreciably diminishes the muddying of clothes and stockings.

There is still the case of the sparsely used footway. Here the loyal walker keeps himself near the kerb on the one pavement, and near the houses on the other. So far as mud is concerned, this should average out to give a semblance of equality with the present regime. In fact, however, there would always be some walkers approaching in the opposite sense, or overtaking, and if the "keep left" habit is once acquired these can be passed with the same aplomb and free stride as if the pavement were quite clear.

NATURAL RELUCTANCE TO HELP FLOW.

To all arrangements for flow we must expect opposition, because interests are various. The passer-by may wish to pass, but the shopkeeper wants him to dally in his street. No vendor, of course, believes that the total number of purchases made will, in fact, be less because the toilers get back to their homes earlier and less weary; it may even be more, but each individual shopman who has learnt to hang out his bait, on the basis of past fishing experience, may fear lest the shoal be disturbed. He often dislikes the institution of one-way streets, roundabouts, the keeping of pedestrians to the left, the shop-gaters limit line, the localizing of crossing places, the shifting of the stopping places of 'buses—there may even be some misguided enough to say that they dislike

freer traffic flow—until the serious meaning to them of its cessation comes back to their mind. Shopkeepers are a significant power in the formation of public opinion—for, inevitably, they influence publicity—since they influence advertisement.

There will be other oppositions; thus male “nuts,” women in their best clothes, and other “class-conscious” persons in all grades of clothes will be liable to betray that they are not apt for social life and freedom by their greedy and callous walking. At present there is no “walkers’ code of the road,” and not even the best will in a few walkers can leaven the mass. The crying need is for an authentic “code of the road”—notably because of accidents.

ACCIDENTS RATIO.

If an excuse is wanted for discussing the pedestrian it can now be given. His two urgent needs are the lessening (1) of accidents and (2) of traffic congestion; and since 70% of road fatalities involve pedestrians (I refer to the last 1926 statistic of Greater London, which shows three killed per day) they have the premier claim.

A demand for “less traffic accidents per day” is typical of the man in the street who wants less accidents, and puts in the words “per day” to make it more scientific. If some Deity, for choice the one who inspired the words “what fools these mortals be” granted this gift in the simplest way, he would do so by stopping the traffic. The man—nay, the town—would go hungry in a week and starve in a month. We would have no pedestrians killed per day by traffic, but we would realise that the need for traffic flow is imperious, and that what we want is really “less accidents per quantum of traffic flow,” which is not the same as the previous prayer. So different is it that the cure suggested by the new phrasing is almost the opposite. That is to say, instead of wanting to diminish the flow to lessen the accidents per day, it ought to be the well-informed pedestrian who demands an increase in the amount of traffic flow per accident, and he will do so as soon as he has realised that this is the only humane and the only tolerable and economic way of lessening distress in relation to traffic. Traffic flow is a simple name for a complex notion. The amount of traffic flow in a day means the number of tons of traffic, say 100 tons, conveyed some number of miles, say 100 miles in that day—and the entire accidents problem is how to convey each 100 tons all these miles in a day with the least casualties. Until quite lately, when roundabouts and one-way streets were tardily granted us, the method of impeding one day’s traffic so that it should take two days had been the inspiration which the man in the street sought to infuse into the traffic control in this and other countries. Congestion has resulted, accidents have certainly not diminished (in Greater London they have increased much more than the traffic increased since 1920), and the walker is worse off. He gets little in exchange for the handicap to transport which he has asked for.

To produce a lot of inconvenience without doing good is the sign and token by which we recognise bad legislation. Patent as this may seem, the walker will still want to know how he in particular will fare with the freer flow of vehicles through the congested areas. His gain economically from quick cheap transport he may concede, but what does he gain in safety?

Light is thrown on this by police records of the speeds at which fatalities occurred in each year since 1920. In Greater London (and surely no locality has a more complete range of contrasted wide roads and constricted alleys with both thin and dense traffic), the bulk of fatalities occurred at slow vehicle speeds—and the majority of fatalities were to those on foot. Seventy-eight per cent. are noted under 15 m.p.h., compared with only 9% between 15 and 20 m.p.h. We know there is a deal of driving in Greater London above 20 m.p.h., and, indeed, at 30 m.p.h., yet we find less than 5% of fatalities at all higher speeds above 20 m.p.h. This was in 1926; in every previous recorded year the results were analogous.

How to divide the number of killed pedestrians among the various vehicle speed groups is not exactly known, but the difference is so large between the 78% at slow speeds and the 5% at fast speeds, that even if all the 5% were pedestrians, the great majority of the pedestrian fatalities must have occurred below 15 m.p.h., and of these a large number under 5 m.p.h. Here is the the analysis for 1926 :—

Speed of vehicles,	1 to 5 m.p.h.	5 to 10 m.p.h.	10 to 15 m.p.h.	15 to 20 m.p.h.	Over 20 m.p.h.
Number of killed.	208	366	221	98	45
Per cent. of total killed	20%	36.5%	22%	9.8%	4.5%

(NOTE :—The percentages do not add up to 100% because there is a residue of unknown and stationary fatalities making up the 100% in the year).

At this point I must accentuate the wide difference there is between desiring an increase of traffic flow and desiring an increase in the speeds of the vehicles which constitute that traffic. I take an example. When local repairs introduce a constriction of the road between London and Coventry traffic flow is diminished, but there will, and I surmise that in fact there *did* result an increase of vehicle speeds on the London-Coventry road.

Now, I am not using the table above to advocate that the fast speeds of vehicles should be increased. I would as soon they were reduced, but what I urge is that the integral of the speeds, that is the traffic flow, should be increased by smoothing away every cause of congestion. Inference from the Table confirms one's daily observation that there are in London, or any big town, inordinate

and growing amounts of arduous, slow, very difficult, and therefore dangerous driving to be done in constricted places. The massing of vehicles which results from the constrictions and the strain on the drivers are both contrary to the pedestrian's interest and safety. If he makes long waits before crossing he suffers in his precious time ; if he is impatient and threads his way through the moving maze he suffers in his precious person.

Deductions from statistical tables must be guarded, but it would seem that even in an area of mixed town and country like Greater London, where the need of quicker safe transport is very great, a plea against improving the traffic flow on the ground that greater vehicle speeds are necessarily associated with more frequent fatalities, pedestrian or other, fails to find support.

Arguments against a better average speed of the emotional kind are more difficult to deal with. There are righteous persons who have declared themselves annoyed, imperilled, frightened, deafened, vibrated, splashed, dusted, delayed, hurried, and their friends hurt and killed by vehicles moving at fabulous rates. They possibly speak truly, but they have stored up so much "Christian spirit" that they are more prone to condemn all speeding up in a comprehensive damn than to abet the "maximum safe traffic flow." This spirit of retribution and of "I'll pay them out" against motorists is bad policy for the pedestrian, and it is dwindling—when it is gone, all parties can join *con amore* in attacking and with success misdeamours, nuisances, noise, vibration, dazzling, drunken driving, failure to stop, etc. To-day all parties are beginning to realise that speed is the merit and *raison d'être* of motor traffic ; this is a great advance. Another good sign is that we find a non-motoring body, the Safety First Council, pleading for self-discipline among the walkers. Town walking will soon be both safe and speedy if this mental attitude develops.

An impediment to the introduction of increased safety measures among walkers is their sense of injured innocence. This may be natural, in view of their fragility in traffic, but it is not warranted. Dogs who play in the street are equally fragile, and feel equally innocent and are equally mistaken. Pedestrians *cause* many traffic accidents between vehicles, indeed drivers are far more often compelled to dangerous passes by pedestrians than by dogs. The London and Counties Traffic Advisory Committee finds that there is "an ever increasing use of the streets by pedestrians unequipped by habit, knowledge, or experience to protect themselves against the new hazard" (of the growing traffic).

That they are often responsible is plainly stated. Pedestrians are not infrequently the cause of accidents and, moreover, in these accidents "persons (other than the pedestrians causing them) are sometimes killed or injured."

Even a fraction of the walking population flushed with over confidence, inexperience, a sense of grievance, convinced of their prior right of way, having great rapidity in pivoting, reversing and changing their minds, having no

customs or code of road behaviour to steady them in times of panic, no agreed means of showing others their intention to proceed, or stop or swerve, are a serious menace and danger to themselves, to other pedestrians and to all the drivers they meet. The remedy for this trouble is as simple as the dose of oil; what is hard is to bring the pedestrian to the decision to take the dose, given hereafter as the "Walkers' Code of the Road."

(a) Walkers should divide into two streams on the footways by keeping as far as possible to the left of the pavement space when there is a pavement.

(Keeping to the left is seriously preferable to keeping to the right, because this arrangement makes the walker face the oncoming vehicles on his side and the advantage of this is that if he is crowded off into the road he steps off seeing the vehicle, and not with his back turned towards it.)

(b) Walkers should, when there is no footway, prefer the right-hand side of the road—for the same reason—facing the traffic.

(c) Walkers should facilitate others' progress—notably remember to allow themselves to be overtaken or passed—especially when walking in pairs, or trios.

(d) Shop-gazers should move near to the shop—giving priority to those who are passing. It would be good if they and those who wait for buses would repeat the words:—"They should also *swerve* who only stand and wait."

This short walkers' code, of four items, might usefully be contrasted, since it provides a comparable list of self-denying ordinances, with the long schedule of self-imposed and other restrictions used by the vehicle traffic—not that road traffic units are any more virtuous, but that they have earlier felt the advantages of a code. The lesson was no doubt brought home to them the more effectively that some items have been given the force of law where a custom is stiffened by penalties, and they have accordingly been tried with that universality of adoption which can most surely make road custom fruitful of good; be it noted that whatever the reason, among motorists there are on the *tapis* numbers of new suggestions for more customs—always of a self-denying kind, yet always securing a good following. This attitude is lacking among walkers.

Walkers and drivers alike require that Parliament shall nominate some single traffic authority whose word shall be final as to what is at any date the custom of the road or footway to be followed—whether as a local experiment, or as a more permanent general habit. Such an authoritative declaration of the code of customs need not, and I think *should not*, convey that lapses from the selected custom are punishable in any way—the situation, intentions, business, moods, capacities and temperaments of pedestrians are too various to be covered by any mandate, since this would have an enormous list of

exceptions. This undesirability of a mandate with penalties seems to be used as an excuse by the Government for shirking the duty of finding, declaring, fostering and publishing the "road code of walkers" which is so sadly lacking. The preparing of a code necessarily involves cutting out *one* of all pairs of clashing customs—e.g., keep to the left *versus* keep to the right of the footway either of which is better than nothing—but England, from the Prime Minister downwards, contains no person or body that can select which; without the risk of being asked quite rightly—who appointed *you* to tell us what is what? This was the fate of the Safety First Council, when it benevolently tried to help the walkers in this way.

EDUCATION BY POSTER.

To reap advantage from the "Walkers' Code of the Road" and from the resultant orderliness, speed and freedom it must become widespread. Iteration and publicity could be got by notices on lamp posts and the like without rent charge—by the goodwill of Municipal and Urban Councils. It would greatly help if the stores and shops would also prefer the "*Keep Left*" formula thus making universal the habits for both men and vehicles.

Public authorities and railways could advise it on all footways, bridges, platforms, stairways, arcades, theatre gangways, lavatories, auction rooms, hotels, football grounds, race meetings, etc., and stations, "Keep well to the left" notices should be put up as a matter of public spirit. Careless folk will be with us always, but it might become the mark of the educated man, and notably of the educated motorist and cyclist, that when he walks on the footway as well as when he drives on the road he *always* keeps to the left of the available space,* and here I invite aid from the Royal Automobile Club and the A.A. and the C.T.C.

EDUCATION BY SLOGAN.

Up to 20 years ago the car, bus driver, carriage driver, cabby and coster nculcated the customs of town driving on one another and enforced them by the sharp weapon of caustic speech. This weapon, which the motorist regretably cannot use to chasten his erring but fleeting brethren is available to the pedestrian. I do not advocate, but I can picture the day when a forgetful or selfish blocker of the footway will spring to one side on hearing the word "Please," lest it be followed by remarks, wafted from nowhere in particular, such as:—"Foot Hog!" "Greedy" "Capuchin Ape" or "Bought the road?"

HORSED VEHICLES.

Vehicular and pedestrian difficulties have this in common. They can be eased at little expense if the units of both traffics will try to be considerate—

*Further refinement for those who are indifferent as to which of the two pavements to take would be to prefer the right hand pavement, though of course on the left side of it.

but they can get nowhere by uncombined goodwill. They must trouble to learn how.

In 30 years the motor traffic has taken its place in a flow which has centuries of horse tradition. The horsed vehicle exists, and counts; it caused 10,000 accidents in Greater London in 1926; its lower capital value makes it the cheapest vehicle when the "user" involves waiting periods sufficiently long compared to the ton mileage to be done in the year. Such long standing periods may be a total due to loading or unloading, as at the docks, etc., or it may come in large doses owing to the varying use made of the vehicle or to seasonal delays as in the case of farm carts.

The horsed vehicle has its full rights to the road; it was on the road first as was the walker. Its technical peculiarities have determined, and still influence road construction in manners which clearly concern pedestrians. Its ability to turn in an extremely small radius is responsible for the too sharp pavement corners of our towns. Its lack of horse power is responsible for the expensive and tortuous character of roads where the gradient has been studied to the detriment of the directness—or of the economy, which could easily be achieved if either the motor car or the pedestrian were in question. The innate reluctance of any horse to step upon a man or other living animal used to provide an additional safeguard for pedestrian, dog and stray beast, and this has given to walkers in the road a traditional but, at present, unwarranted sense of security by day and night. The liability of the horse to shy, and his possible objection to pull when on the sloping side of a cambered road, have probably retarded by centuries the acceptance of the otherwise obvious and desirable road custom of keeping all vehicles always to the extreme left of the available road space.

OLD TIME CONGESTION.

It must not be imagined that horsed traffic was more silent or, in London for example, less hampering to the pedestrian than is the mixed traffic of to-day. Indeed, a writer, Mr. McCaul Watson, in *The Times* July, 1927, quotes G.P.K. James's biography to show that in 1858 at the "Oxford and Regent Circus, where the two finest commercial thoroughfares cross, it is no unusual circumstance to have to wait 15 minutes for a chance to get over on foot."

What we have to accept at present is that the inclusion of the horsed vehicle in the stream of motor vehicles though detrimental to the flow of that stream must be borne till at some possibly imminent stage of traffic development in certain localities the point will be reached when that detriment outweighs in the general interest the restricted economic advantage of the horsed vehicle, through its low first cost.

When that time arrives and the horse is barred, it is my belief that the pedestrian will profit by the diminished congestions and the better regulated flow of motor traffic in such places. This is not the usual walkers' view.

He likes to use the shelter of a horsed cart for his own purposes in crossing the traffic stream. This is typical of a great difficulty in making any progress in traffic control, traffic regulation and traffic flow. Many pedestrians' outlook is on the whole non-constructive, some would even call it obstructive on all traffic problems, including the pedestrian problem itself. Here is an example.

NON-STOP ROUNDABOUTS.

The essential quality of the roundabout and the only one that gives it any virtue is that it substitutes continuous flow for the former "stop and be crossed" system. A pedestrian could on reaching a roundabout gain time and lessen his risk by proceeding to his destination without crossing the circle of roads which carry the non-stop circulation. The utmost increase of his path in doing this is in the ratio of the half-circumference to the diameter of a circle. From pure thoughtlessness, and from not appreciating what the roundabout is for, he is often to be found aimlessly and dangerously wending his way among the tangle of vehicles; at such points of infiltration their movements appear to him disordered and incomprehensible. I suggest it would be a good custom for him to avoid these roadways in his own interest, and that notices counselling this be put up, and subways (or bridges) assisting him be put down.

A PEDESTRIAN REFUGE AT A ROAD JUNCTION.

A walker along the footway of, say, a main street in town, must, in continuing his walk, step from the footway in order to cross the mouth of some side road. Instantly he becomes a unit of the roadway traffic, that is, of a traffic which has the duty and habit of deciding its behaviour entirely by foreseeing the intentions of other units.

He pauses. Having no pre-arranged code he has no means of disclosing his intentions in relation to even one vehicle. The anxiety of his countenance, and the variable pointing of his nose or umbrella are inadequate to reveal intention. Even if he is versed in the code of the road for vehicles (of which there exists unfortunately no authoritative publication), he will be pleased to find that the road mouth which he is crossing has a central "refuge." This will allow him to pause and readjust his attention before braving the second stream. He is right to be careful, for he is defenceless in the very middle of the well-recognised complexities of "traffic at road junctions."

He notes at once that the more orderly the traffic the better for him, for example, the "refuge" is chiefly his standby, *not* because it is raised four inches above the road floor—an obstacle any car can climb—but because the two streams of vehicles are by it thoroughly warned to their proper sides (a just appreciation of orderliness in others! they should keep well to the left!) It irks him to wait long either on the kerb or on the refuge for a chance to cross. (An appreciation of the ills of congestion); he wants space and

intervals. (An appreciation of traffic control—for others). He is disconcerted when a car in the main stream, which appeared to be continuing down the street unexpectedly turns the corner towards the side road, and that may be just when he is about to step into it. (An appreciation of the use of "show their helm!" So much more polite than saying "boo!" at him, and less noisy, too!). Above all he would like to know what precisely *all* the vehicles will do when he is in jeopardy; and not knowing, of course, he "wishes there was a policeman" (in fact, by this wish he has appreciated the value of some one who will make enough delay for his own direction of movement to "show his intention" for him.) Please note that stepping on to the road floor converts him to quite useful thoughts on traffic behaviour and flow provided he keeps his head. His dislike of the congestion was merely the negative expression of a wish for a safe freer flow—How can this be got? How can the cars in the side road "show their intention" to turn the corner, and how can the walker be given the code he so sorely needs in order to make his own intention known.

There is also the walker who will think none of these things, but who only wishes for the impossible, that the traffic be stopped when and wherever he has to cross. He is merely, though very legitimately, scared. His thinking apparatus has stopped, which is a pity, but he is not the individual from whom to draw any help for the solution. The thinking walker has endorsed as favourable to himself precisely what the drivers want on their own account.

Having been enlisted on the drivers' side, what trouble is the walker prepared to take to find out if the rest of the driver's needs are also in his real interest?

Now take the drivers' point of view. A motor car driver leaving a side road to join the stream of a main street can show his intention easily enough if the mouth of the side road is "flared" by a large rounding of the pavement corners, for he can slope his car the way he proposes to go. (He can show it earlier still if he carries an intention indicator on his windscreen, though that is a separate matter). But if the pavement corners are kept as abrupt as they are now, every driver at the mouth of a side road must face his car at right angles to the main stream whether he is going to turn left or right. He is physically prevented from "showing his helm." That is regrettable, and if curable, it is wrong. I advocate flaring the pavement corners of the side road; but this is also going to concern the walker, because it means either a wider crossing (or if he dislikes that, going two or three paces up the side road before he crosses, and so obtaining the old width of crossing). These paces out of his direct line are a sacrifice or an advantage, according as he gains *time* or loses it by conforming to a general scheme which forwards all traffic movement.

*"Road Traffic Congestion and other Problems," a lecture on 15th November before The World Road Transport Congress at the Savoy Hotel, by M. O'Gorman.

The flaring of pavement corners should not be allowed unfairly to rob the footway in favour of the road way, on the contrary, the stolen pavement area should be restored to the pedestrian as a central refuge. The complete operation consists in taking away some pavement which impedes vehicles, and putting it in a place where it assists pedestrians. So everyone gains.

In the past there has been too much of the opposite method, namely, filching a piece of roadway from the vehicles for a pedestrian island without restoring any equivalent of roadway area where it is badly wanted. This is specially bad for traffic flow when the refuges are placed in the course of the road and not only at corners. In as far as such refuges prevent overtaking they limit the flow rate to that of the slowest vehicle present. That is always bad.

Island refuges are to the good and are to be encouraged, but on condition that the road width at and near the island is not reduced. In practice the pavements should be shaped to restore to the road its full width and so avoid a number of local causes of congestions. The effective width of a road is its narrowest width.

Island refuges have, in my estimation, been frequently ill placed, but in the absence of any aerial survey measuring small increments of traffic flow neither I nor anyone else can be dogmatic. My impression is that they are usually too far forward towards the road cross and that the wooden test refuges are only capable of assisting against downright malplacing.

No human being is quite consistent. The average walker when in the road traffic thinks that he is very much afraid, but when he is on the footway, confronted with a subway, clean, electrically lit and free from vehicles, experience shows that he is not afraid enough of the road surface risks to cross by underground means. The existing tunnels are largely neglected yet he gets hurt in these roads. Assuredly it is over-confidence, not laziness that explains his neglect of facilities—not confidence in himself—but strangely enough confidence in that brute of a motor driver's willingness to slow for him, steer to save him, warn him, befriend him—at the expense of traffic flow.

I resume in few words the general contentions and aspirations of this paper. They are that :—

1. Pedestrians are very vulnerable and defenceless traffic units, conspicuously hampered in their progress.
2. Observation of traffic units of all sorts has disclosed canons of individual behaviour which favour traffic flow.
3. The canons of traffic behaviour are based upon the considerateness, voluntary or enforced, of each traffic unit for the other traffic unit's progress.
4. Expression is given to this considerateness by the double dictum "Show your intended direction and study the other fellow's."
5. To keep to your "proper side" is to show your intended direction

- and incidentally to respect the other fellow's, whether he would overtake—or would pass you.
6. Pedestrians ignore the canons of traffic behaviour on the footways and are, therefore, not attuned to their inflexible enforcement when they step into the roadway.
 7. This unpreparedness of pedestrians is evinced by their having no agreed signal for "turn right," "turn left," "stop," "swerve" or "reverse" by which to show their intention to other traffic.
 8. This unpreparedness is maintained and fostered by
 - (a) A belief that there is a pedestrian's "prior right of way" which overrules the rationalized laws of traffic flow.
 - (b) Unconsciousness among pedestrians that by neglecting the canons they occasion frequent accidents among other traffic units.
 - (c) A consequent sense of grievance among pedestrians, which seems to entitle them always to blame the others and, therefore, be in the right themselves.
 - (d) A mistaken notion that no man would imperil his life to save his time (whereas many a man is known to have lost his life to save his hat).
 9. No claim is made here, or I believe, anywhere, that pedestrians are always in the wrong in relation to other traffic classes. But I do claim that they are almost always in the wrong as regards one another.
 10. I demand that the Transport Minister study and then publish an authentic code of *Road Customs*.

DISCUSSION.

MR. E. SHRAPNELL-SMITH, C.B.E. (Chairman, Commercial Motor Users' Association), in opening the discussion, said he desired to say how much he had enjoyed the paper, and complimented the author upon his original method of treatment of the subject, and the intriguing character of some of his proposals. The proposal to regulate the pedestrian in his own interest was a very novel one to Britishers. Personally he re-called that when that suggestion had been put forward by himself at a meeting over which the Minister of Transport had presided only a year ago in Caxton Hall, the idea of regulating the pedestrian, and, in certain contingencies, even imposing penalties upon him, had caused headlines to appear in all the papers of this country, and had also resulted in his (the speaker) receiving a most acrimonious correspondence. It had even been flung back upon him when he had recently been on a political platform in a certain division of London.

With reference to subways, and to the impossibility of making the British public use subways, to those who had gone into the matter it was clear that unless some means were found to persuade pedestrians to cross the road in an orderly fashion the high incidence of accidents would continue. Until subways were provided with escalators, which would result in the pedestrian seeing that there was something to gain by his making for a particular point at awkward round-about crossings, the average Englishman—including himself—would persist in crossing the road as

they had done for many years past. One could not try to cross the new round-about crossings without having to admit that they constituted a new and deadly terror for the walker. Therefore something must be looked forward to of the nature of escalators, and he would suggest that the crossings at St. Martin's Church and Piccadilly would be very good points for such an experiment. Until they were fitted with escalators the subways would never be used.

With regard to the suggestion that pedestrians should give signals, he viewed that with some doubt. There were many hours in the day in London where the occurrence of passengers was as 10 to 1, 15 to 1 and 20 to 1 on the vehicles; and if a driver were to encounter two pedestrians together who gave different signals, in addition to having to watch the traffic which was "weaving," as it was now termed, it would result in some difficulty and confusion.

With regard to the question of the "stolen" pavement, Col. O'Gorman brought out most clearly the importance of placing the refuge in the right position in the highway and of rounding the kerb of the pavement edge at corners inwards instead of outwards, in order to give back to the highway the traffic space which was taken for the refuge. Experience in Paris and America pointed to the necessity for this.

The publication by the Ministry of Transport of an authentic code of road customs was one of the lecturer's favourite themes, and one which deserved to be cordially supported; but when he proceeded to urge a code for people on the pavement, and suggested that the disregard of such a code should not be punishable at the present time, he certainly agreed with him that penalties were not yet for the pedestrian. Personally he ventured to say that, if a code of customs for the footway were drawn up, it would have to be treated as an element to be considered in the case of any accident rather than as something which was absolutely arbitrary. He might point out to the lecturer that, from the report of the London Traffic Committee, the number of deaths due to stepping off the kerb, which was the outcome of bad pavement organisation, had shown a very marked decrease. According to Table 13 (a) of that report, in 1922 they were 11.3 per cent. of the total fatalities to pedestrians in the Metropolitan Police area; in 1923, 13.1 per cent; in 1924, 9.6 per cent; in 1925, 11 per cent. and in 1926, only 9.4 per cent. Therefore, possibly, the cause of death by stepping off the pavement without looking was helping to solve itself; and although the re-organisation of pavement traffic, whereby people could look into shop windows better and get along more quickly, was unquestionably desirable, it seemed to him it had not such a direct bearing upon street traffic fatalities as the author might perhaps feel.

With regard to persuading people to go to the left instead of to the right, there was the disadvantage that if one kept to the left on the footwalk and was then going out into an area where the footwalk ceased, and one then had, as the lecturer suggested, to walk facing the oncoming traffic, one had to walk to the left on the pavement and to the right on the highway; and that meant crossing the traffic to carry out those two injunctions. When the Safety First Council made most strenuous efforts, with the co-operation of many municipal authorities, to bring that rule about, they found they made no progress.

He was delighted at the fact that the lecturer brought in the question of mileage—a conditioning factor in accidents. People were very fond of missing out mileage. One read that in London, for instance, the accidents in the non-tramway streets were almost equal to the accidents in the tramway streets, but it was not stated that there were many more miles of tramway streets than of non-tramway streets. It would be seen at once when mileage was brought in, that the tramway streets were an enormous danger both to pedestrians and

cyclists. He thought mileage per vehicle and mileage of streets should unquestionably be taken into consideration.

Although he was interested in road commercial traffic, every effort of his, and of the Societies with which he was concerned, was in the direction of endeavouring to persuade the pedestrian to take care of himself—not with any desire to speed up traffic without regard to the pedestrian, but rather to enable the pedestrian to save himself from injury.

COLONEL R. E. B. CROMPTON, C.B., said that everyone would agree with the lecturer in what he said about regulating and improving the traffic on the footways. Personally, he lived close to High Street, Kensington, and it was dreadful to see the congestion of shop gazers in front of Barker's windows—eight or nine persons thick, all with their backs to the roadway traffic. It was really a wonder that so few accidents occurred. Nevertheless he had to confess that the habits of the walker had improved to a most extraordinary degree. He found now that not only active people but old and infirm people were able to cross the road without accident much better than they ever did before. The same applied to nervous old ladies and to dogs and even to cats. It was most interesting now to see old ladies looking to the right and left, and also to see their dogs looking to the right and left, before crossing a thoroughfare. Cats did the same thing, and the result was that the total number of accidents had been enormously reduced. At High Street, Kensington, the number of accidents formerly used to be at the rate of about one a day, but nowadays no accidents occurred at all because everybody was so skilled in crossing the road.

He was the unfortunate possessor of ideas of his own on the constructive side. Some of the audience might have read his article in the *Fortnightly Review*, July, 1926, in which he had tackled the subject very thoroughly. He had taken his ideas before the police; they had been very seriously considered, and many of the suggestions he had made, such as white lines on the roadway, and so on, had been adopted. He had written that article for the main purpose of making the crossing for the walker an easier matter. If one watched the traffic on any of our roads one saw a procession of vehicles coming along; sometimes they were locked up close together, and sometimes there were great spaces between them. When those spaces occurred, then there was ample time for walkers to cross the road. All skilled persons waited for those spaces to arrive before they crossed. He had suggested that those gaps in the traffic should be made compulsory and regular. At present they were most irregular. One found a line of vehicles about 30 yards apart streaming along the road. If they closed up to ten yards apart, there must be a gap—and a gap through which it was easy for a pedestrian to cross. At the time he had written his article he had made a number of observations, and he had found that it was very rarely indeed, in our most congested streets, that the roadway was occupied for more than a third of what it would carry if the traffic was regulated properly. He had found from that that the average through speed of the traffic could be greatly increased. The lecturer had observed that if the speed of traffic was doubled the road space available was increased. People did not realise that. For instance, if the speed of traffic proceeding from one point to another at eight miles an hour was increased to 16 miles an hour the roadway would have double the crossing spaces for the walker. He had suggested, as the fact that there was slow traffic and fast traffic had to be faced, that all the main streets should be divided into four lines of traffic, the line nearest to the kerb moving slowly and the outer line moving at the maximum possible speed, and that the police should regulate

the outer line into trains, which would leave gaps of an extraordinary length, even at the worst time of congestion, through which the pedestrian could cross. On Oaks Day in Piccadilly he had watched the traffic and had found that the trains could be 300 yards long and the gaps nearly 600 yards long. The time must come when, in order to utilise our streets for wheeled vehicles to the greatest extent, they must be regulated into trains and into regular lines.

A most potent source of accident to the walker was the fact that he left the sidewalk crossing at the back of a passing vehicle and suddenly an overtaking vehicle caught him, with a resultant accident. He suggested that an extra signal was required on the part of drivers of vehicles when they were about to overtake other vehicles in front of them. If the overtaking vehicle driver gave clear warning that he was about to overtake a slower vehicle, that would prevent accidents to the crossing pedestrian who had chosen what he thought was the right time to cross behind the slower moving vehicle which was next to the kerb.

COLONEL KENYON VAUGHAN MORGAN, M.P. said, as representing the Western Exits of London Society, it might be interesting to those present to know that although that body had done a great deal of work, they had not so far attained that measure of success which they perhaps deserved and certainly desired. At the same time they lived in hope, and he could assure those present who were interested in their endeavours that they were pressing on, and hoped at no very distant date to gain a satisfactory measure of progress. When they did so they would have helped not only road traffic but also the pedestrian, because their proposed road, when it became a *fait accompli*, would provide a most admirable opportunity for the pedestrian to experiment in the way which the lecturer had so eloquently described. He had enjoyed very much the delightful way in which Col. O'Gorman had presented his subject. One of the things he had enjoyed more than anything else had been the lecturer's very apt, witty and graceful description of the function of legislation. It was all very well to make laws, but it was quite useless to make laws which were not supported by the general consensus of opinion of the nation whom they were intended to control. On the other hand, when there was public support for an idea it became an easy task for the legislature. One thing which stood in the way of so many projects to-day was the difficulty, owing to the pressure of business, of getting a measure carried through the House of Commons.

LT.-COL. J. A. A. PICKARD, D.S.O. (General Secretary, National Safety-First Association), said he noticed that the title of the paper was "Road Traffic Problems of the Pedestrian," and he had rather hoped to have heard some advice given to the country pedestrian. A good deal had been said about the difficulties of the town pedestrian, but on some of the country roads the problem of the country pedestrian was a very pressing one. It was not so much a question of what he ought to do as to where he could go. The provision of footpaths for pedestrians in the country, or for places where they would be safe, was most necessary.

His Council entirely agreed with what the lecturer said about the need of further good-will and co-operation between all classes of road users. That was going to be the secret of greater safety on the road. Each different class of road user should realise the difficulties and the dangers of the other classes.

With regard to legislation, we were different from some other countries. Some countries passed legislation and then bludgeoned people into carrying it out; whereas in this country we did a thing first and then passed laws to record the fact that we were doing it; in other words, we built up first a code of customs.

He joined issue with the lecturer over the question of statistics. The lecturer had quoted statistics from the London Traffic Report which went to show that the faster one went the less the number of accidents ; in fact, that did not mean that if one drove at, say, 60 miles an hour no accident occurred at all. That was rather a dangerous argument. Danger did not lie in speed qua speed ; it lay in the relation which speed had to all the circumstances of a case. As a matter of fact an analysis of fatal motor accidents during June and July revealed that excessive speed, having regard to all the circumstances of the case, was by far the most outstanding cause of all fatal accidents.

MR. CURZON HARPER said the lecturer had stated that if a pedestrian would walk a third faster he would use a third less space, but personally he did not think that was always true. If a pedestrian walked a third faster he would get home earlier and would then probably decide that he had time for another walk, and perhaps would take his wife to accompany him. He had also been going to raise the point about speed and accidents to which the last speaker had referred. He thought it would be found that most of the slow speeds occurred at awkward and congested places, and that accidents were due to the awkwardness and to the congestion rather than to the slow speed. For instance, taking a rather exaggerated example, a car could go at one hundred miles an hour at Brooklands, and yet he did not think there had ever been a single accident to a pedestrian recorded at that place ; but that was due to the fact that it was at Brooklands and not to the speed of one hundred miles an hour.

DR. HEINZ SPRANGER (Medical Officer of Health, Friedberg) spoke of the necessity of educating school children in the matter of how safely to cross the road. If the present generation were taught how best to cross the thoroughfares, the next generation would be much freer from the likelihood of accident.

During his stay in this country he had been astonished to find that motor vehicles had no automatic signals to show which way they were going to turn. The present method of indicating with the hand was rather futile, especially in heavy traffic and at awkward points, when a driver had to use both hands for his wheel and brakes. Another point was that an attempt should be made to solve the problem from an international point of view. At present the traffic in this country proceeded on the left, whereas in many other countries it proceeded on the right. The result was that when Englishmen went abroad or when foreigners came to this country confusion resulted. As an example of that, several weeks ago a Czecho-Slovakian, whose country adopted the left-hand rule, met with a serious accident with a car driven by a German, in whose country the right-hand rule prevailed. After the accident the Czecho-Slovakian said that he did not know that there was a different rule in Germany from that in vogue in his own country.

MR. L. GASTER pointed out that the London Safety-First Council had endeavoured some years ago to bring about a rule that all pedestrians should keep to the left, thereby facing traffic, but they had not been successful in obtaining the desired unanimous support of the police for this idea. In his opinion, uniform procedure in this matter could best be secured by appropriate legislation.

MR. M. O'GORMAN, in his reply, partly communicated, said he welcomed Mr. Shrapnell-Smith's kindly reception of his proposals. As regards the use of subways at road crossings, one must not overstate the intractability of the pedestrians. They

were easy to lure if hard to drive. They won't go into a sort of cellar of glazed bricks; but experiment would show how to make subways attractive. At some centres escalators would do, or the gay effect of illuminated show cases of goods along the subway walls would both attract and produce revenue from renters. Once the subway habit was formed the show cases might have to go, to make room. The substitution of slopes for steps might help, also it was important to remove the inference that a subway meant lavatories. The overground risk would never operate to fill the subways till that risk were notified, for example, by placards saying "*Subways are Safer*," or other catch phrase. Support the Safety First Councils with subscriptions and they will do this class of work well.

Mr. Shrapnell-Smith rightly considered that the existing disordered horde of pedestrians could not usefully give signals of intention to vehicles, since their signals would conflict—that was one reason why signals are not to be advocated till the rudiments of road behaviour have been assimilated.

He particularly welcomed his support as chairman of the C.M.U.A. for his contention that no one should advocate penalties for pedestrian breaches of good custom. That would kill the whole campaign. If walkers were convinced that they were being offered guidance only, and that disinterestedly, they would adopt customs, they would copy one another and police one another quite enough. He did not agree that there was any need to cross the road, when there came a change from pavements to no pavements, save for a fraction of the walkers, viz., those on the left pavements.

He agreed that he had concentrated on the single objective to enable the pedestrian to save himself.

Col. Crompton's report that the judgment of walkers in High Street, Kensington, was improving, gave encouragement. Walkers were intimately concerned with the proper spacing of vehicles for maximum traffic flow since this would permit of good pauses in the flow for pedestrian crossing, but such crossing should be on the "keep left" principle, to avoid all "nose on" meetings in the middle of the street.

Col. Vaughan Morgan's support for his remarks was much valued, since he had worked so disinterestedly at the subject. He agreed with the implication in Col. Pickard's remarks, that footways in country roads were sadly and badly wanted. The essential need for forming a code of customs was accentuated in Col. Pickard's remarks, and, therefore, he too must wish for the institution of some interpreter of the public will who should state authoritatively what the customs are—and even add, in an advisory sense, what new customs might usefully be. That authority should be the Transport Minister—whose office should, therefore, be continued and strengthened. He thought that if Col. Pickard would read the paper again, he would nowhere find the view that the faster one went the less the accidents—nor that excessive speed was not a cause of accidents, but he would find that the greater the *safe* speed of flow, the better for everyone, including the pedestrian. In addition to that, the lecturer differed from Col. Pickard's analysis of the statistics. Mr. Curzon Harper had correctly seized the point, namely, that the slow speeds occurred at congested places, and these caused the accidents. He (Mr. O'Gorman) still maintained that by walking $\frac{1}{2}$ faster the streets would be 33% clearer, because of the facts of life which Mr. Harper overlooked. After going home when the man went out again—with or without his wife, it would not be back to the congestion, where workers were leaving their work, but in the far larger area of the suburbs, etc., where the people dwell or into the neighbouring country. Thus the congestion would be and remain scattered.

Dr. Stranger indicated the best thing that had yet been done, viz., the education of the young folks in how to treat, respect and walk in traffic. If only the "keep

left " and other customs were authentically codified, this instruction of the young would practically solve the pedestrians' risks in a few years, but until they were authoritative, no one could with sanity teach a code—for fear it should clash with the code taught at the next school.

He thoroughly agreed with Dr. Stranger that mechanical devices to show intention ought to be used on vehicles to be visible from in front, from the side, and from behind in *all* situations. The hand signal was quite insufficient. Dr. Gaster had illustrated one of the lecturer's points. In England there existed 1,300 road authorities, in London about 94 authorities. Any one of these could block a large and statesmanlike solution. Until there was one authority over large areas, the position was hopeless, and the failure up to date of the existing system in London condemned it.

Col. Crompton had spoken of the danger of the overtaking vehicle. He supported the suggestion that there should be a distinctive signal to indicate that a driver meant to overtake. He would also suggest to Col. Crompton a little slogan: "If you don't attend to the overtaker, the undertaker will attend to you."

THE CHAIRMAN, in proposing a vote of thanks to Col. O'Gorman for his paper, remarked that it was very interesting to study the habits of pedestrians, who had all their curious little traits. One which had particularly struck him was that when people were about to cross at a difficult corner, if they could possibly manage to do it, they would invariably walk out two or three feet into the road and wait, which, of course, made it more difficult for the drivers of vehicles. Then, again, two men in the way of a vehicle either both went backwards or forwards and invariably scowled at the driver, whereas if there were two ladies in the way one would go one way and the other would go the other way, and then both would turn round and smile to the driver. That had invariably been his own experience. The more narrowly one missed a lady the more she turned round and smiled.

He was certain that if there was a definite code for pedestrians the number of accidents would be greatly reduced. Many accidents arose from the fact that a man or woman, when they met with certain traffic difficulties, had not any code to go by, and did not know what they should do.

The vote of thanks having been carried unanimously, the meeting terminated.

OBITUARY.

MR. JAMES CAWSON.—We regret to announce the death on November 4th, at the age of 76, of Mr. James Cawson, who had been a member of the Society since 1898. Mr. Cawson was much interested in accountancy matters, and had recently acted as Chairman of the National Anti-Profiteering Society. He was a regular attendant at meetings of the Royal Society of Arts, and frequently took part in discussions.

NOTES ON BOOKS.

DISAPPEARING LONDON. By E. B. Chancellor. London: "The Studio," Ltd. 5s. net.

It must always be difficult to adjudicate satisfactorily between the claims of the past and of the future. Even a community stable in numbers and good ~~some~~ would occasionally be faced with problems of reconstruction that would divide it

into two or more camps. But in the present state of the world, considering the great power of monied interests with no feeling of obligation towards the arts, most people who regard themselves as civilized (rather than progressive) tend to wish to protect everything good that has been inherited from the past.

In the case of "Disappearing London" there is reason enough why innovators are to be feared. They pull down London, and as likely as not set up New York, or Schenectady, or wherever it may be: some Middle Western city, perhaps, but certainly not a true component part of our metropolis. It is a rare delight to get a building such as Sir Edwin Lutyens' Midland Bank, by St. James's, Piccadilly.

We have Mr. Williams-Ellis's word for it that Bush House has good manners. Many kind things have also been said about the new Devonshire House. But surely this need only be compared with the dignified and really urban Ritz Hotel opposite for its barbarousness to become obvious. Seen from halfway down a street of character, like Curzon Street, which has proportions relevant to human stature and to human activity, Devonshire House has the air of a tenement.

It is over Regent Street that there will continue to be most controversy of the kind here implied for some time to come. The erecting of the Piccadilly Hotel was the first blow at Nash. However, Norman Shaw, who designed it, was responsible for a European hotel in a tradition congenial to the London environment, while the greater part of the new street is perfectly undistinguished, and might as well be in China or Peru as in London.

One must add, in fairness, that on the average the new architecture, though often lacking any definite character, is superior to that of the phase which preceded it. For example, the new piece of the Criterion in Lower Regent Street is better than the old piece in Piccadilly Circus. And, after all, there is a certain amount of good building going on. An interesting new house is to be seen at the north-east corner of Lincoln's Inn Fields. The College of Nursing, in Henrietta Street, designed by Sir Edwin Cooper, is sensible and attractive both inside and out. Instances could be multiplied up to a modest figure.

In "Disappearing London" we have collected by Mr. Geoffrey Holme a series of etchings by various artists to help us remember the once familiar outlines of vanished edifices. An interesting preface by Mr. Chancellor tells of the demolitions of former ages. Insufficient watch is kept for relics of those and still remoter ages, when building operations are in progress. Two years ago a public-spirited gentleman collected fragments of about thirty pre-Roman, Roman and medieval jugs, mugs, etc., on a big site that was being cleared in the City. These he wished to hand over, not to the contractors, but to the community. The thanks he got were threats of an action for receiving stolen goods!

How can one look at Plate VII, "Piccadilly Circus, looking north," by Randolph Schwabe, without feeling sad? ● P.B.

THE ELEMENTS OF TELEPHONE TRANSMISSION. By H. H. Harrison. With Diagrams. London: Longmans, Green and Co., Limited. 5/- net.

Here we have a concisely and carefully written first book on that important branch in practical construction which deals with the conditions under which a circuit transmits sounds with economy and the utmost practicable perfection in rendition. The teachings of Heaviside, although much neglected when they first appeared, have led to developments by Pupin and many others; and in reading the various works the student drifts into difficulties, owing to diversity in methods of representation and treatment. Mr. Harrison specially mentions the vagueness with which many writers introduce the subject of hyperbolic functions.

The mathematical introduction, pp. 1 to 36, is intended to clarify or elucidate the primary concepts in such a way that the variations in treatment by the more advanced writers may cease to trouble the student, and Mr. Harrison explains the nature and use of the natural, hyperbolic or Napierian logarithms (pp. 2-3), as also the continual approach to infinity (pp. 10-11) as giving an easy view of the Newtonian doctrine of prime and ultimate ratios. After the first chapter we have many well-selected problems bearing on every day work. Thus, despite the author's statement in the preface that the work is "not a practical text book," we are inclined to think that many students will take a different view.

IDEAS AND STUDIES IN STENCILLING AND DECORATION. By A. Desaint. Charles Griffin & Co. 15/-.

There is no need to take offence at the self-assuredness of this useful book, which opens *con brio* and continues in the same temper. Stencilling is a bold craft, and Mr. Desaint's letterpress, type, paper, binding and examples are characterised by boldness. It would be a good thing if technical instruction were more often given as clearly. Nowhere could more explicit advice be found on the processes connected with this form of decoration; the line illustrations of the tools employed are the height of realism; plate 1, with its forty colours and appended tables of colour combinations, is invaluable.

When it comes to discussing the plates that follow one naturally cannot be quite so wholly eulogistic. Experience has afforded Mr. Desaint knowledge of the sort of effects to which stencilling lends itself; it is no wonder—and no reproach—if these strike some of his readers as being on the conventional side. No doubt more can be learnt by the beginner from a study of such forms than from any more modern conceptions (or more sophisticated ones), which would quite possibly make a bad point of departure.

The idea of stencilling in distemper is good, seeing how popular distemper is nowadays. A distempered frieze of polar bears in the bathroom or of teddy bears in the nursery can be charming. This is a craft which, in the hands of an original worker, may yield the most attractive results; but it seems doubtful whether it can be as universally employed as the author of this efficient book believes.

P.B.

GENERAL NOTE.

APPLIED ARTS AND HANDCRAFTS EXHIBITION AT THE ROYAL HORTICULTURAL HALL:—The Fifth Applied Arts and Handcrafts Exhibition will be opened at the Royal Horticultural Hall, Vincent Square, Westminster, on Friday, December 2nd, and will continue daily from 11 a.m. to 8 p.m. until December 9th. The Exhibition which has a large number of distinguished patrons, will cover a wide range, and will include jewellery, hand-painted lampshades, pottery, hand-loom weaving, book-binding, wood-engraving, lacquer-work, cabinet-making, lace and embroidery, etc.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, NOVEMBER 28. Actuaries, Institute of, Staple Inn Hall, Holborn, W.C. 5 p.m. Mr. H. E. Raynes, "The place of ordinary Stocks and Shares (as distinct from fixed interest bearing securities), in the investments of Life Funds."

Automobile Engineers, Institution of, at the Royal Technical College, Glasgow. 7.30 p.m. Captain C. H. Kuhne, "Military Transport Vehicles—Recent Development and their Commercial Significance."
East India Association, at Caxton Hall, Westminster, S.W. 3.30 p.m. Pandit Shyam Shankar, "Political Views of Orthodox Hindus."
Electrical Engineers, Institution of, at Armstrong College, Newcastle-on-Tyne. 7 p.m. Mr. E. S. Cohen, "Apparatus Standards of Telephonic Trans-

- mission and the Technique of Testing Microphones and Receivers."
- Philologie, Sciences et Beaux-Arts, Société Internationale de. 3.30 p.m. Major R. Rigg, "The London Associations of John Milton."
- University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Prince D. Svyatopolk Mirsky, "The Russian Novel, 1845-1880." (Lecture VIII.)
- At King's College, Strand, W.C. 5.30 p.m. Rev. C. F. Rogers, "Ecclesiastical Music." (Lecture III.)
- 5.30 p.m. Dr. H. G. Atkins, "Heine, a Hundred Years Ago." (Lecture II.)
- TUESDAY, NOVEMBER 29.** Anthropological Institute, 52 Upper Bedford Place, W.C. 8.30 p.m. Mr. Y. K. Suominen, "The latest pictures of the Finnish People."
- Civil Engineers, Institution of, Great George Street, S.W. 6 p.m.
- Electrical Engineers, Institution of, at the Hotel Metropole, Leeds. 7.15 p.m. Mr. J. V. Levett, "Oil-Electric Automatic Control of a Hydro Extractor"; Mr. H. Moss, "The Contractor's Place in the Industry." At the Engineers' Club, Manchester. 7 p.m. Messrs. A. H. Law and J. P. Chittenden, "Higher Steam Pressures and their Application to the Steam Turbine."
- Metals, Institute of, at the Engineers' Club, Waterloo Street, Birmingham. 7 p.m. Dr. G. D. Bengough, "Corrosion."
- North-East Coast Institution of Engineers and Shipbuilders, at Cleveland Scientific and Technical Institution, Middlesbrough. 7.30 p.m. Mr. W. C. Freeman, "The Production and Modern Applications of Dissolved Acetylene."
- Opticians, British Practical, at 8, Taviton Street, W.C. 8.15 p.m. Dr. E. H. Griffin, "Some Common Causes of Blindness."
- Photographic Society, 35, Russell Square, W.C. 7 p.m. Dr. C. V. Drysdale, "The Wave Theory and Measurement of Lens Aberrations." (Traill Taylor Memorial Lecture.)
- Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Sir William Bragg, "A Year's Work in X-Ray-Crystal Analysis." (Lecture II.)
- University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Sir Bernard Pares, "Russian History to 1861." (Lecture VIII.)
- At King's College, Strand, W.C. 5.30 p.m. Miss Hilda D. Oakeley, "The Philosophy of Personality." (Lecture III.)
- WEDNESDAY, NOVEMBER 30.** Electrical Engineers, Institution of, at the University, Edmund Street, Birmingham 7 p.m. Messrs. P. R. Coursey and H. Andrews, "Battery Eliminators."
- Geological Society, Burlington House, W. 5.30 p.m. Mr. C. W. Osman, "The Granites of the Scilly Isles, and their Relation to the Dartmoor Granites."
- North-East Coast Institution of Engineers and Shipbuilders, at the Bolbec Hall, Newcastle-upon-Tyne. 7.15 p.m. Mr. B. Reed, "Boiler Performance."
- Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Prof. Dr. Blair Bell, "The Prevention of Cancer."
- University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. Dragutin Subotić, "Serbo-Croat Mediaeval Literature." (Lecture I.)
- At King's College, Strand, W.C. 5.30 p.m. Mr. Herbert Ward, "The Training College."
- At the London School of Economics, Houghton Street, Aldwych, W.C. 6 p.m. Mr. J. J. Walsh, "Management Statistics."
- At University College, Gower Street, W.C. 3 p.m. Dr. C. Pellizzi, "La Lirica del Paradiso." (in Italian.) (Lecture I.)
- THURSDAY, DECEMBER 1.** Aeronautical Society, Royal, at the Royal Society of Arts, John Street, Adelphi, W.C. 6.30 p.m.
- Chemical Society, Burlington House, W. 8 p.m. Messrs. T. A. Henry and H. Paget, "Action of Beckmann's Chromic Acid Mixture on some Monocyclic Terpenes." Messrs. R. Grindley and F. L. Pyman, "The Condensation of Glyoxalines with Formaldehyde." Messrs. W. Hubball and F. L. Pyman, "Glyoxaline-4 (5)-formaldehyde." Messrs. G. F. Smith and T. M. Lowry, "Studies of Dynamic Isomerism. Part XXVI. Consecutive Changes in the Mutarotation of Galactose." Messrs. O. L. Brady and C. V. Reynolds, "Triazole Compounds. Part II. Methylation of some 1-Hydroxy-1:2:3-Benzotriazoles." Messrs. D. R. Boyd and D. E. Ladham, "The Reaction between Diaryloxyisopropyl Alcohols and Phosphorus Oxychloride in the presence of Pyridine."
- Child-Study Society, at 90, Buckingham Palace Road, S.W. 6 p.m. Dr. Cloudeley Breton, "Can Artistic Appreciation be Taught?"
- Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m. Mr. R. B. Matthews, "Electric Ploughing."
- Linnean Society, Burlington House, W. 5 p.m.
- L.C.C. The Geffrye Museum, Kingsland Road, E. 7.30 p.m. Mr. C. A. Hindley, "Period Furniture of the 19th Century."
- Mechanical Engineers, Institution of, at Glasgow. Sir William H. Bragg, "Application of X-Rays to the Study of the Crystalline Structure of Materials." (Thomas Hawksley Lecture.)
- Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Dr. R. E. M. Wheeler, "London before the Norman Conquest." (Lecture III.)
- University of London, at Bedford College for Women, Regents Park, N.W. 4.15 p.m. Prof. Ecoles, "Voltaire: les meilleurs moments et les plus belles pages." (Lecture IX.)
- At King's College, Strand, W.C. 5.15 p.m. Mr. G. B. Harrison, "Jonathan Swift."
- 5.30 p.m. Mr. Geoffrey Shaw, "Hymns at the Present Time."
- 5.30 p.m. Mr. Ifor L. Evans, "Peasant Proprietorship in South-Eastern Europe." (Lecture VI.)
- 5.30 p.m. Baron A. F. Meyendorff, "The Crisis of Communism." (Lecture I.)
- At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Prof. Dr. Ludwig v. Mises, "Economic Theory and the Social Problem." (Lecture I.)
- At University College, Gower Street, W.C. 5.15 p.m. Prof. de Montmorency, "Customary Law in the British Empire." (Lecture V.)
- 5.30 p.m. Dr. C. Pellizzi, "Benedetto Croce e i suoi maestri." (In Italian.)
- 5.30 p.m. Miss E. Jeffries Davis, "London Place-Names." (Lecture IV.)
- Victoria and Albert Museum, South Kensington S.W. 5.30 p.m. Mr. Eric Gill, "The Future of Sculpture."
- FRIDAY, DECEMBER 2.** Chemical Industry, Society of, at Milton Hall, Deansgate, Manchester. 7.30 p.m. Dr. J. A. Bowie, "Coal and Co-partnership."
- Geologists' Association, at University College, Gower Street, W.C. 7.30 p.m. Dr. S. W. Wooldridge, "The 200-foot Platform in the London Basin."
- Mechanical Engineers, Institution of, Storey's Gate, S.W. 6 p.m. Mr. E. G. Herbert, "Report on Cutting Temperatures: their Effect on Tools and on Materials subjected to Work."
- North-East Coast Institution of Engineers and Shipbuilders, at the Mining Institute, Newcastle-upon-Tyne. 6 p.m. Mr. A. L. Ayre, "The Essential Aspect of Form and Proportions as affecting Merchant Ship Resistance and a new Method of Estimating E.H.P."
- Philologie, Sciences et Beaux Arts, Société Internationale de, 8, Taviton Street, W.C. 8.15 p.m. Mr. Harold Bellman, "The Silent Revolution—The Progress of the Building Society Movement in England."
- Philological Society, at University College, Gower Street, W.C. 8 p.m. Dr. O. Vocadio, "Purism."
- Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. A. H. Blake, "The Pictorial Aspect of Old Buildings."
- SATURDAY, DECEMBER 3.** L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Mr. C. Daryll Forde, "Natural Man."
- Royal Institution, 21, Albemarle Street, W. 3 p.m. Mr. Gustav Holst, "Samuel Wesley and Robert Pearsall."

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FRIDAY, DECEMBER 2nd, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK.

MONDAY, DECEMBER 5th, at 8 p.m. (Cantor Lecture.) PROFESSOR H. C. H. CARPENTER, M.A., A.R.S.M., F.R.S., "Alloy Steels, their Manufacture Properties and Uses." (Lecture IV.)

WEDNESDAY, DECEMBER 7th, at 8 p.m. (Ordinary Meeting.) S. J. DULY, M.A., Head of the Department of Commercial Products, City of London College, Mitchell Student for 1925-6, "The Damage to Cargo due to Ship's Sweat." CAPTAIN SIR ARTHUR WELLESLEY CLARKE, K.B.E., Elder Brother of Trinity House, will preside.

FRIDAY, DECEMBER 9th, at 4.30 p.m. (Indian Section.) SIR DAVID T. CHADWICK, C.S.I., C.I.E., "The Indian Tariff Board." SIR CAMPBELL RHODES, C.B.E., will preside.

FUND FOR PURCHASING THE SOCIETY'S HOUSE

The following offer has been received from a Fellow of the Society :-

"As a help towards the Fund for purchasing the freehold and covering the cost of renovating and decorating the Society's House, I will add 5 per cent. to every contribution up to a total of £2,000 received from now to the end of June, 1928, for that purpose.

WM. RUSHTON PARKER, M.D."

The Council earnestly hope that friends of the Society will give them an opportunity of profiting by Dr. Rushton Parker's generous offer.

The total amount required is £50,000, of which £43,401 14s. 5d. has now been subscribed.

DR. MANN JUVENILE LECTURES.

Under the Dr. Mann Trust, PROFESSOR ARTHUR SMITHELLS, C.M.G., D.Sc., F.R.S., Director, Salter's Institute of Industrial Chemistry, will give two

lectures for children on "Flame," at 3 p.m. on Wednesday, January 4th and 11th. The lectures will be fully illustrated by experiments.

Special tickets are required for these lectures. A sufficient number to fill the room will be issued to Fellows in the order in which applications are received, and the issue will then be discontinued. Subject to these conditions, each Fellow is entitled to one ticket admitting two children and one adult. Fellows who desire tickets are requested to apply to the Secretary at once.

SYLLABUS.

LECTURE I.—This will be a continuous series of experiments beginning with a candle flame and showing how we can explain the shapes and parts of flames and, in a way, take them to pieces. It will be shown how different gases give different flames and how the flame of any one gas may be altered by the way in which it is burned.

LECTURE II.—This will illustrate by experiments the use of flames for lighting and heating, beginning with the old ways and showing how improvements have been made. There will be experiments with the Welsbach mantle and with the steel cutting blowpipe flame. The proper use of gas in the house will be illustrated.

FOURTH ORDINARY MEETING.

WEDNESDAY, NOVEMBER 23rd, 1927. A. F. SUTER, ESQ., in the Chair.

A paper on "Malayan Varnish Resins," was read by Mr. T. Hedley Barry. The paper and discussion will be published in the *Journal* dated December 16th.

CANTOR LECTURES.

MONDAY, NOVEMBER 28th, 1927. PROFESSOR H. C. H. CARPENTER, M.A. A.R.S.M., F.R.S., Professor of Metallurgy, Imperial College of Science and Technology, delivered the third of his course of four lectures on "Alloy Steels, their Manufacture, Properties, and Uses."

The lectures will be published in the *Journal* during the Christmas recess.

PROCEEDINGS OF THE SOCIETY.

INDIAN SECTION.

FRIDAY, NOVEMBER 11th, 1927.

SIR HENRY STRAKOSCH, G.B.E., in the Chair.

THE CHAIRMAN said the subject of the lecture that evening, Indigenous Indian Banking, was one that was both interesting and, in view of its close connection with the question of establishing in India a true Central Bank, very important. He hoped the discussion on the paper would be an exhaustive one and would

be of help to those who would be called upon, in accordance with the proposals of the Indian Currency Commission, to study the subject of indigenous Indian banking. He thought it would have been quite possible to be without a Chairman at that meeting because Mr. Gubbay hardly needed an introduction, being well-known both in this country and in India through his long and distinguished career as a public servant of the Government of India, and latterly as General Manager of the P. and O. Bank. Mr. Gubbay's career in the Public Service was a very distinguished one. He filled the important posts of Collector of Customs at Bombay, Wheat Commissioner for India, Controller of Currency, and finally Financial Secretary of the Government of India. All those functions had brought him into close contact with the subject on which he was reading the paper.

The following paper was then read:—

INDIGENOUS INDIAN BANKING.

By M. M. S. GUBBAY, C.S.I., C.I.E.,

General Manager, P. & O. Banking Corporation, Ltd.

I propose to discuss in this paper the position, as it presents itself to me under existing conditions, of two important groups in the Indian banking system. The customary description of this system distinguishes on the one hand between the organised banks, that is, Banks working on joint stock principles, and the private Indian banker, that is, the Shroff, Chetty, mahajan, working on private account and outside the provisions of the Companies Act. As to the organised Banks, these again are classified according as their capital is in sterling or in rupees, and their management and control is outside India or in India. Among Banks with rupee capital and local management, the Imperial Bank is differentiated from other joint stock Banks with rupee capital and local management, and these latter, again, are distinct from the Co-operative Banks working under special statutory provisions. The purport of this paper is to attempt an appreciation of the present and future position of the Joint Stock Banks with rupee capital and local management, and of the private Indian banker, under the general scheme which is being evolved as the outcome of the Royal Commission's recommendations for the reform of the Indian banking system.

The Government Statistics on Banking recorded the existence in 1925 of 74 Joint Stock Banks. Their paid-up capital and reserves aggregated Rs. 11.78 crores: their deposits Rs. 57.91 crores. These 74 Banks include 46 Banks whose capital and reserves ranged between 1 lac and 5 lacs, and whose deposits amounted to under Rs. 3½ crores. The balance Rs. 54.49 crores was distributed among 28 Banks: and among these six Banks between them accounted for no less than Rs. 47.30 crores. Of these six Banks, two, the Bank of Baroda and the Bank of Mysore, are the Bankers of the Indian States in which they operate: they do not fall, therefore, in the same category as the remainder whose activities are purely commercial, and who have not the advantage of acting as State or Government Bankers. Of these four institutions, which are

really the sole important instances in India of purely private enterprise engaged in banking on a joint stock basis, two are of Bombay origin, the Bank of India, and the Central Bank of India : the Punjab National Bank, as its name implies, originated in the Punjab ; and the Allahabad Bank in the United Provinces. This latter Bank enjoys the distinction of being by far the oldest of these Joint Stock Banks, having been founded in 1865. Having established itself in the United Provinces and the Punjab and Central Provinces and formed a strong and extensive local connection in the mofussil it has moved its headquarters in recent years to Calcutta. It affords a solitary instance, among Banks of its kind, of the entry of a purely mofussil Bank into the commercial banking of a Presidency town. In all other cases where branch banking has been part of the policy followed, the development has been outwards from the Presidency town. Another feature which is common to these Banks is the persistence of separate individual organisations : with the exception of the Central Bank of India, which has absorbed the Tata Industrial Bank, there has been no case of fusion or amalgamation.

The chief business of these Joint Stock Banks is concentrated in the Presidency towns, the large sea ports, and the more important commercial centres up-country. It is here alone that opportunities offer, on a large scale, for the suitable investment of banking funds. The branches act as feeders, the funds that they can attract being mostly remitted to the Bank's offices at the chief commercial cities. Suitable local investments are not, as a rule, available to these Branches. The borrowing propositions which come before a Branch Agent rarely conform to the requisite standards of security or maturity. In most cases personal security, or a personal guarantee of another party is offered : where house or landed property is tendered as cover for accommodation the advance is usually required as a continuing loan, liquidation to be spread over an extended period. This lack of suitable banking investments available to Branches has a twofold effect. In the first place it results in the rates which Branch Banks can offer for deposits being determined, not by the measure of the local demand for accommodation, but by the rates at which these deposits can be invested in well-secured short term commitments at the commercial centres. In the second place it forces the Branch Bank to leave to other agencies, generally to the private Banker, the function of supplying the local needs for accommodation.

We have here one important factor to account for the slow development of branch banking in India. High rates of interest prevail in the Indian Bazaar, and very notably in the mofussil bazaars. Some evidence of bazaar rates for money is available in the Controller of Currency's Reports. The Report for 1927 gives the Bazaar Bill rate in Calcutta as between $10\frac{1}{2}$ per cent. and 11 per cent. ; these are the rates at which the bills of smaller traders are discounted by Shroffs. The Imperial Bank Hundi rate in 1926-1927 did not exceed 7 per cent., and was as low as 3 per cent. in the slack months : the Hundi

rate of the Imperial Bank is, of course, the rate at which that institution will discount or rediscount first class three months Bills; and, in practice, this rate has reference to Bills which bear the endorsement of a Shroff whose signature is acceptable to the Bank. Of mofussil rates there is no regular official record; some line can be drawn from the rates prevalent in Bombay and Calcutta: and from the rates at which Chetties, who are largely engaged in financing internal trade transactions in Madras and Burma and Ceylon, borrow from organised Banks. Advances to Chetties are generally on the basis of 2 per cent. above Imperial Bank Rate with a minimum of 7 per cent. Bank advances on grain, seeds and produce are generally on the basis of 8 to 9 per cent. Looking to the margin between the rates which Banks pay for deposits and these rates, it might seem that there should be a large scope for the remunerative employment of funds in the mofussil. But, in point of fact, the position is quite the opposite. The high rates which can be earned in the mofussil are, to a large extent, caused by the fact that banking funds can only, to a very limited extent, be employed in the mofussil; the security which is offered to cover an advance is not suitable; in a general way it is known that the funds are required to finance the movement or purchase of produce, or of imported goods: the drawer of the Hundi or the borrower may be known generally to be engaged in the marketing of produce or imported goods; the Bill or the advance purports to be based on goods purchased or about to be purchased: but there is, as yet, under conditions as they exist in India, no means available to the Bank to connect the Bill or advance with any particular lot of goods or produce: sale contracts, invoices, documents of title are usually not tendered in support of the Bill or advance. It rests really on the general security of the assets of the parties to the bill or the borrower. There will, of course, be cases in which it is possible to secure the segregation, from among the borrower's general assets, of the particular goods which are to represent the security on which the bank can rely for its advance, but such cases are not the general rule. In the vast majority of instances the business offering is on the basis of the borrower's general credit position—without hypothecation of any particular assets as cover for the accommodation desired.

Branch Banking has, for these reasons, very largely left this business to the private Indian Banker to handle, and has, in the main, directed its activity in the mofussil to the purpose of securing deposits for use at the Presidency towns and the larger commercial centres. Naturally there must, in the circumstances, be a great disparity between the rates which Banks can offer for funds, and the rates which the bazaar can afford to pay, and can expect to earn in bazaar operations; and this disparity has affected the power of Banks to tap local funds in competition with the bazaar. Much has been said and written about the urgent necessity of developing banking habits in India. There is no manner of doubt whatever that the wider use of the cheque, in place of the currency note and the silver rupee, is an essential requirement from

all points of view, and I am in entire agreement with the policy which has resulted in the exemption of the cheque from stamp duty. I do not doubt, also, that the recent expansion of the Branch system of the Imperial Bank will have a great effect in the direction of stimulating the use of the cheque. But progress in this direction will not, by itself, put before Branch Banking in India a clearer prospect of greater development. I imagine that the experience of the Branches of the Imperial Bank is not sensibly different from that of the Branches of other Banks. It is, perhaps, possible that, because the Imperial Bank has the use free of interest of Government balances, and has also the means, through the Government account, of cheapening to the trader the cost of transfer of funds between one inland point and another, its Branches can offer to traders facilities on terms more favourable than those which other banks can afford; and will, thereby, show a degree of development which, statistically, will give cause for satisfactory comment. But if this development, as is claimed by the other Joint Stock Banks, does not represent, substantially, that organised banking is taking a larger share in the financing of internal trade transactions, it must be conceded that it is premature to express gratification at the numerical increase of offices where banking facilities are available in the mofussil.

This difficulty which faces organised banking in its penetration in the mofussil may be considered from another aspect. In a general way, it is known that the part played by organised banking in the financial life of the people of India is inconsiderable when contrasted with that which is played by the private Indian banker. There are no precise data available as to the extent of the operations of the latter. He is to be found everywhere, in every village, town and city in the country. The type ranges from the small village capitalist to the wealthy, well-established private partnership, generally a family partnership of merchant bankers which has agencies in and outside India. A special type is that of the Chetty community in Madras, where there exists something approaching to joint responsibility of the community as a whole for the liabilities of individual members of the community. It is known that in many cases accounts can be maintained with these Indian bankers on which operations by cheque are permissible, and I have been informed on good authority of one case at least in which on such current accounts as high a rate as 6 per cent. is allowed. It is also known that funds lie with these Indian bankers on time deposit, at rates much above those which are available from the Banks. Occasionally, when disaster overtakes one of these private bankers, figures are mentioned of their liabilities to private persons, which point to their ability to attract considerable sums. I see no reason to doubt the commonly accepted view that both because these private bankers can afford to pay attractive rates of interest, as well as because their requirements as to security are less rigid, their participation in the financial life of the community, as a whole, must be on a very extensive scale. Further, they are in intimate daily touch with those

with whom they transact business, and can follow the doings of their clients with a closeness which is denied to the Banks. There must be accumulated with these private bankers a store of knowledge and experience of the standing, moral as well as financial, and capacity of individual Indian traders and Indian trading firms, their business connections and relations on which, if fully organised and systematised, might possibly quite suitably rest an expansion of credit facilities from the Banks.

As things are, however, at present, the only link which we find between the Indian banker and the Banks is supplied by the endorsing Shroff to whom I have already referred. It is the signature of the Shroff, who is on the Bank's list of approved shroffs, which renders acceptable to the Banks the Bill which traders draw. For each Shroff the Banks have specific limits up to which they will accept paper bearing his endorsement. As to what is behind the paper so made, nothing definite or precise is known. A differentiation is professedly made between paper drawn to finance commercial transactions, and "hand hundies," which are pure finance paper: but as in neither case are any documents tendered to the Banks in support of the paper, the differentiation can only rest on general assumptions. In practice the real basis is the personal standing of the Shroff, supplemented by such knowledge of his general transactions and procedure as can be ascertained by investigation. Some scrutiny is applied by the Banks to the names of the makers of the paper which the Shroff endorses: the frequency of the same names may, and does, cause Banks to reject paper made by such parties, even though it may bear the endorsing Shroff's signature. The functions of the endorsing shroff, it should be noted, do not resemble those which, according to European banking practice, are associated with the accepting merchant banker. The business of the endorsing Shroff is the investment of funds, whether his own, or deposited with him by other parties, in hoondees. So long as he can carry these hoondees unaided by Bank funds, he will do so. He looks for his profit to the difference he can secure between the rates at which he can borrow funds, and the rates at which he can employ them in hoondees. As Banks do not compete with him for the purchase of traders' hoondees, the hoondi rate in the bazaar has little relation to Bank rate, and is determined by the Shroffs themselves. When seasonal movements of produce, or of imported goods, occur so as to cause the supply of hoondees to increase to a point beyond the capacity of the Shroffs to finance them, resort is had to the Banks: and endorsing Shroff's limits are then fully utilised.

The operations of the Shroffs lie outside the influence of the organised Banking system of the country, and are, on the whole, very little affected by the credit policy of the Banks. Only a fractional portion of the demands which the Shroffs supply being derived from Banking funds, and then only at times of temporary stringency or pressure, it follows that the Banks cannot interfere to moderate the suddenness of the transition between excess and, shortage, or

vice versa. This cause may explain the variations which we find, from experience, to be common in India in the demand for money at different periods of the year. This aspect of the problem will assume an increasing importance when and if a Central banking authority is called into existence whose function is to be to control credit as well as currency policy. Hitherto, as the Royal Commission has quite rightly observed, there has been no real effective control of the credit situation by any authority, within or outside the Government. Such control as has been possible at all has been through the fact that bazaar operations and the general transactions of the country have had to be conducted with silver or note currency, and credit requirements have had to some extent to follow the supply of currency available. But, if we are to assume that an expansion of operations by cheque is to set in in India, and payment by cheque displaces in the bazaar and in the mofussil payment in silver or note currency, what means are available to secure for the Central authority an effective control over the credit operations of the bazaar?

This question appears to me to be of primary importance, and its solution does not appear to me to be simple. I quite appreciate and understand that a new and increasingly important role will fall to be played by the approved commercial bill in the new equipment which is under construction for the Indian banking system: I can also see that means can be adopted both by the State and the Central authority to encourage the practice of financing by means of Bills. Quite possibly, under the effect of these means of encouragement, the cash credit system may, in course of years, give way to the Bill, though I personally anticipate that the process will be slow and gradual. But, even assuming that the change comes about rapidly, we shall still be left with the position that there will be lying beyond the influence and reach of the Central authority a very considerable, perhaps a preponderatingly large amount of financial and commercial transactions which, in the hands of bazaar dealers in credit, will be only indirectly responsive to Bank rate policy. The regulation of the credit policy of the organised Indian joint stock banks presents no difficulty: these institutions are already in sufficient contact with those charged with Bank rate policy to be sensitive to its effects. But neither they nor the Imperial Bank have so close an association with the bazaar as to be in a position to moderate or govern the operations of the bazaar dealers in credit. If the Central Authority is to rely on its own open market operations to make its policy effective in the bazaar, it will only be able to do so by directly assuming commitments which the experience of other Institutions has taught them to avoid, and I do not doubt that this experience will be severely respected. The question then turns on the possibility of bringing about a modification of the basis on which the bazaar hoondie is now grounded, so that the latter will conform, in those essentials, to the requirements which will make it acceptable as a suitable investment for Banking funds. This change will at best be slow in coming, and an essential preliminary is an investigation of the conditions

which now obtain. An extensive and scientific survey of banking conditions formed one of the recommendations of the Royal Commission, and such a survey must necessarily include the study of the means for broadening the channel between the bazaar and the Banks, of enlarging and quickening the contact between these two elements in the Indian banking system, and of securing that credit operations throughout the whole system will respond to the policy of the Central Banking authority.

DISCUSSION.

MR. E. L. PRICE, C.I.E., O.B.E., said he hoped he would not be censured for any irrelevancy, but the subject was rather difficult, especially from the point of view which the lecturer had taken. He had extended the definition of indigenous banking to Joint Stock Banks modelled on severely British lines, and he would put it to the lecturer that when a Madras gentleman came to London and took his M.D. and returned to Madras and practised Western medicine, would he be inclined to call that indigenous medicine? It was Western medicine practised by an Indian, not empirically, but based on Western methods and training. Indigenous banking should be confined to the operations of the mahajans, Marwari bankers, shroffs, and so forth. The ordinary man was not worrying about any of those names; he had one word for all of them, *bania*. For that there was a very good and substantial reason. All that so-called "banking" was largely usury, and it was mixed up with dealing in the necessities of life, seed and so forth, and the rates charged, an anna in the rupee per month, were on the basis of 75 per cent. per annum, plus compound interest reckoned monthly, which must actually come to 100 per cent. That was a very common affair. His own feeling was that the lecturer had given rather greater credit to those institutions than they deserved. They were essentially the money-lending fraternity, usurious; and the bulk of the money they lent consisted of their own family funds, not deposits collected in the ordinary banking way. He should like to go back to the essential basis of banking. In the case of Insurance everybody would recognise at once that however it might be organised it was essentially a co-operative business. Some people formed themselves into mutual societies, but in other cases the company was really only the manager for the accumulated risks and liabilities. It was the same with banking. He had read the Report of the National Provincial Bank, and he noticed that the amount due to the shareholders for the capital they put up was just under 7½ mill ons, and the amount due to the depositors for what they had put up was 260 millions. That meant that in banking proper the shareholders' put up enough money to make the expert organisation, but practically the whole trading capital of the bank was put up by the depositors. It must be much the same in India. The shareholders' returns might seem very handsome from a dividend point of view, but from the point of view of the balance sheet they were a very small item, and from the point of view of the turnover they were absolutely insignificant. If that essential fact had only got into the minds of those who opposed the original Government proposals for an Indian Reserve Bank, he could not think they would have taken the course they did. They exaggerated the importance of the share capital and the dividends payable thereon; from the very start it was going to be limited and the profits over a certain amount were to go back to Government. That Reserve Bank was held up and all that it implied, and he was shocked to see it suggested in the *Statist* the other day that the Imperial Bank

of India might be patched up and carried on as a reserve bank. The man who wrote that could not be aware of the facts. The Imperial Bank of India as a bankers' bank had failed wholly and irretrievably. He was not saying it was its own fault. As soon as the Imperial Bank was constituted out of the old Presidency banks the Government forced upon it the multiplication of branches, and there were now one hundred branches. The net result was bad. It was forced into a sort of commercial banking, and as a natural result it had to desert its previous province of bankers' banking. He believed branches were established by the National Bank of Australia, but had seldom heard of them being found anywhere else. It was certainly not the practice of the Bank of England, but was partly the practice of the Bank of France. The Imperial Bank was not in the purview of the Royal Currency Commission, and he did not see at the present time, in the present position of the Imperial Bank with all its hundred commercial branches, that it could possibly retrace its steps and become a bankers' bank. The position of the Imperial Bank to his mind was a very serious one from the point of view of banking in India. The Imperial Bank not only had free money from Government on which it paid no interest at all but was supposed to render certain services, but had obtained large public funds from other bodies. Municipalities, Port Trusts, and a number of old established companies were all bound by their Articles of Association to lodge money with the Imperial Bank, which was the only one in India that paid no interest at all on current accounts. It had no need to, because the money came to it for nothing. It offered no interest as a rule on short period deposits. When he left India at the end of August it was offering $3\frac{1}{2}$ per cent. for twelve month deposits, and if nobody wanted to deposit for twelve months it would not take the money, but it had a Savings Bank Department for petty sums. The Imperial Bank, endowed with free capital funds, handicapped Banking generally not so endowed. The lecturer had said that the deposits in the seventy-four Indian banks were a shade under 58 crores, roughly $43\frac{1}{2}$ million pounds. The population—and he thought the lecturer must have taken All-Indian figures—was 320 millions. Dividing the one into the other it did not come to 3/- per head. There were also the Post Offices, the Exchange Banks and the Co-operative Banks, and lumping them all in and so multiplying the known figures of the 74 known banks by 3, it was not possible to get the bank deposits up to a miserable 10/- per head. When bank deposits from people did not average 10/- a head banking could be hardly said to exist. People were spending their time trying to differentiate the species when they had not established the existence of the genus! There was a meeting of the London Institute of Bankers the other day, and he noticed that the Chairman, Mr. Frederick Hyde, was extremely indignant; he said that a number of people were carrying more money about with them and the bank funds were not so full as they should be, and he wanted to know how the banks were going to finance industry if people ceased to put money into them. How were the banks in India going to finance anything if Indians would not put their money in? If it was said that the deposits were small because the people were poor, what about hoarding? A number of estimates of the hoarding in India had been made, and that hoarding had been going on from time immemorial. In the crucial year, 1924-25, when gold was most required to enable this and other countries in Europe to stabilise currency, India added a good fifty millions to her hoard of gold. The Americans appeared to know something about hoarding in these days, and he felt inclined to take the figures given by the American Trade Commissioner, who put the value of gold and silver hoarded at 1,000 millions sterling. Comparing that with the bank deposits, $43\frac{1}{2}$ millions, it meant that for every £1 banked in India £11 was hoarded. He should like to describe how that hoarding ran from top to

bottom of the social scale. He was at an arbitration not so many years ago and ultimately the parties came to terms, and cash had to be paid—a very large sum of over a quarter of a lakh of rupees. The paying party rose from his chair and produced a neatly-folded, very cheap, probably gaol-made, towel, opened it, and in it there was over a lakh of rupees in currency notes. That man said he always carried his money in that way. There was an Indian he knew quite well who had buried 300 sovereigns for seventeen years, and then dug them up and sold them for 20 rupees each, making a profit, but that profit was nothing to the steady income he had lost during the seventeen years, and he was a poor man. There was a rich man who died, and his sons were in great grief because the old man had bought 5,000 sovereigns and they could not find them; he had hidden them, and they suspected it was in the garden of his country house, but they never found them. They were lost, not merely to the family, but to civilisation! There was a dealer in Bombay, an educated man, who had several banking accounts and large investments, and in course of speculation came into the hands of the Official Receiver. He honestly returned his assets as including over 3 lakhs of silver, which had remained undisturbed in his house for thirty years, and on an estimate he must have lost in interest three times the value of the hoard. The position seemed to him to be pretty desperate. The English banker said that the people must bank their money, and with that money everybody who was producing should be scientifically equipped. Without that money the Indian producer was struggling as best he could with his bare hands, and his efforts of production were low and inefficient. Remembering that £11 was hoarded in India for £1 invested, was it to be wondered that Indian labour was inefficient and that people were ill-educated and ill-equipped in every way? Personally he had great faith in co-operative banks, but ways must be devised to induce people to bank their money and not hoard it, because, while they hoarded, their bad monetary habits were making things much worse both for themselves and the rest of the world.

SIR SELWYN FREMANTLE, C.S.I., said he had been very much encouraged by what Mr. Price had said with regard to the branch of banking in which he was interested, and had been interested for the last twenty years, from the time he was Registrar of co-operative Societies in India. He thought the idea underlying the paper was that in the interest of industry and trade it is highly desirable to extend banking facilities over a wider area. The Industrial Commission in their Report, which was published towards the end of the war, said that there were many small towns in India without any banking facilities at all, and that the volume of business which went on in those towns would be quite sufficient in Europe and America to warrant the establishment of a branch bank, even if it only opened two or three times a week. The lecturer had explained the reasons why even the extension of branches of Joint Stock banks would not be likely to fill that void; the fact was that they did not cater for the small traders or industrialists or agriculturists. The security which the people could give was not such as the bank could accept. Moreover Joint Stock banking in India had received somewhat of a set-back owing to the failure of the banks which were founded in great numbers two decades ago, and which mostly collapsed before the beginning of the war. The failure of the Alliance Bank had been a considerable shock to confidence in Upper India to people who might have been expected to avail themselves of joint stock banks for deposits. The branches of joint stock banks, which had been and were being established, besides keeping current accounts for officials and professional men, had as their function to accept deposits and send them to the commercial centres because they

could not be utilised locally. It seemed to him that urban Co-operative Societies, known as People's Banks, could to a great extent fill up the gap which admittedly existed in the system at present. Mr. Price had made a most interesting speech, and the instances he had given of the amount of money lying idle in hoards all over the country were very striking. He had had experience of it. If in some small agriculturist family 100 or 200 rupees was required to pay a man's fine or costs for a law suit the money always appeared. No one knew the extent of the hoarding of India, but it was very great. It might be said that there were at present a very considerable number of urban co-operative societies in India, but they were mainly in Bombay and Madras, small societies formed amongst employees of a particular firm or small artisans, and they did not as a rule take up the functions of commercial banking. In Germany the popular co-operative banks were very different. There they attempted—and to a great extent succeeded—to perform all the functions of joint stock banks. Ever since they had started they had been in direct competition with branches of joint stock banks, but they had increased and multiplied until now there were over 2,000 of them. He believed they generally advanced money on cash credit accounts the amount of which was secured by bond, but they also discounted bills and so on. The popular banks in Italy were not so numerous, but they were much larger and generally more important. They advanced money against cash credits and also against goods, securities and valuables. Those institutions had done a very great deal for their countries, and the French Government was so impressed by what they had done that in 1917, while the war was going on, they passed a law to establish such banks and for providing a credit for them to the extent of 12 million francs, raised afterwards to 50 million francs. In the course of three years eighty such banks were established. There seemed no reason why banks of co-operative character should not succeed in meeting the wants of the people if joint stock banks failed to do so. There was a very great difference between the two, although to some extent they did the same kind of business. In the first place the shares were kept as low as possible; he believed 100 lire was the largest share in any popular Italian bank, some being as low as 5 or 6 lire, and they could be paid by instalments. The dividend was limited sometimes by law and sometimes by custom, and that, of course, made a very great difference. They took a special interest in the savings of the poor man by giving him special terms, and also by issuing money boxes in order that smaller sums might be collected. The rate of interest charged was very low, 7 or 8 per cent. being the highest rate, and in some cases it was even as low as $4\frac{1}{2}$ per cent. The *castalietto* was a kind of normal credit allowed for each person, and in the case of small people who had nothing except their personal credit, they had officers who went carefully into the objects of loans, and only allowed them when they were convinced of their utility. If such banks were established in India in large numbers they would have the benefit of the advice and help of the Registrar of Co-operative Societies in each Province, which would ensure that their business was conducted in a more or less businesslike way. There would be difficulties in connection with such banks, but certainly not difficulties that could not be overcome, and he thought there was a very great scope for them in India. Another point at which co-operative banking came into touch with joint stock banking was in the arrangement by which each major Province, except one, had a Provincial co-operative bank, which in several cases had got into touch with the Imperial Bank, and had a cash credit account with them. The arrangements had not been long in existence, and were capable of almost unlimited expansion. The matter was of the very first importance, because the time of year when the money was required for agricultural operations, which the co-operative credit

societies chiefly financed, was the time of year, July to October, when he understood there was a glut of money in the Presidency towns. With regard to Land Mortgage banks, it had been recognised for a long time that they were of value in India in order to enable the landowners to raise capital for liquidation of their debts, and for the improvement of their land, the purchase of agricultural machinery and so on. Another matter which was quite clear to those who were acquainted with the history of the agricultural bank of Egypt was that too easy credit was not a thing that should be given to agriculturists, and that mortgage banks should be established on co-operative principles as in Germany and elsewhere. Recently there had been a move in several Provinces towards the formation of such banks, and in the previous week the Bombay Government had developed a scheme by which they would establish a co-operative bank for each area and assist the banks in raising funds. Such banks could be only financed by long term money raised by debentures, and for this the assistance of Government working through the money market was necessary.

MR. A. GOPALJI, M.Sc., said that Mr. Price had expressed himself with great enthusiasm, and if enthusiasm were an argument he had certainly won his case. He appeared to think that Indians could claim nothing to their credit, but he should like him to read some authoritative history of civilisation, and would call his attention to the opinion of Professor A. H. L. Heeren, a great authority from that point of view, who said that the whole civilisation of Europe and of the West had been derived from India. There was also a book entitled "Hindu Superiority," dealing with the subject, by Pandit Harvilas Sarda, a member of the Legislative Assembly, which he would recommend Mr. Price to read. The people of India wished to adapt European institutions to suit their own needs and their own genius, not to imitate them. They wanted all the best. Many European institutions, which had been grafted on India perforce, though with goodwill, by foreign rulers, Indians were now striving to get rid of, because they did not suit their conditions. Indians should not take everything that they saw—all was not gold that glittered. With regard to the question of usury, there was a celebrated classic entitled "'Prosperous' British India," by Mr. William Digby, which showed that the poor people under the stress of Government taxes were driven to the despised *bania*, who enjoyed the protection of the British Government.

SIR CHARLES STUART BAYLEY, G.C.I.E., K.C.S.I., suggested that the *bania* and usury were also to be found in Native States.

MR. GOPALJI said he quite realised that point. Usury was a universal thing and was practised by the people who wanted to make money. The situation had to be realised from all points of view. As the Minority Report of Mr. Thakurdas indicated, the banking system in India was regulated more in the interests of London than India. The Report was thoroughly documented and deserved consideration by those who wished to criticise. With regard to the hoarding habits of the people he thought that was a saving factor of the situation, because, were it not for the hoarding habit, India would have been wiped out of existence long ago. Indians were in existence to-day because of their habits of parsimony. If they were not educated and taught to invest their money why blame them because they did not do so? The paper was a very instructive one, and he asked everyone interested to read the Minority Report which thoroughly threshed out the question of Indian conditions.

MR. FRANCIS SKRINE, I.C.S., (Retd.) said he could give some idea of the state of things in Bengal in connection with indigenous banking. The title of the lecture he thought was somewhat of a misnomer, because three-fourths of it was taken up by the subject of joint stock banks, which were not indigenous, but purely exotic, and the growth of the last few years. Mr. Price had said that the *banias* were usurers, which was rather a hard word. The *bania* in Bengal, *mahajans* as they were called in the Mofussil, performed a very useful, indeed indispensable, function as long as the people were so ignorant as they were. The mahajan's clientèle was mainly composed of cultivators or small traders, to whom he advanced certain sums in cash every year, taking the whole of the crops from the agriculturists, storing them up and disposing of them. He was supposed to credit the cultivators with the profit, and advanced them the necessary seed at the proper time, as well as loans for ceremonies, on which an enormous amount of money was wasted. Without the mahajan the cultivation of Bengal could not go on at all. The problem was very difficult; it was to graft on the system of private enterprise a system of agricultural banks where everyone was responsible—jointly and severally responsible—for advances made to individuals. That was the case in Germany and in Italy, where the People's Banks did a vast amount of good. In India a large amount of Hughli water must run under the Howrah bridge before anything of the kind could be attempted. In Ireland Sir Horace Plunkett had told him that while he was engaged in preaching the gospel of people's banks, he was addressing an audience, mainly agricultural, in the South and explaining the system; an old peasant got up and said, "Shure, what your honour wants is that I shall guarantee £100 for my neighbour, and I will do so if he guarantees the same amount for me." It was a process analogous to kite flying, which was only too common in the towns of Europe. The hoarding habit was universal in India. There were 50 millions of gold absorbed by India in the most critical years through which Europe was passing, when stabilisation was being attempted. India had undergone in the past centuries many invasions, and the general fear of the future made people believe that there was nothing so safe as burying their gold or silver or turning it into women's ornaments. Some native princes set a very bad example in that respect. He knew of an Indian prince who had hoarded 16 million English sovereigns. Mr. Price had estimated the hoards of India at 1,000 million, but he would put it considerably higher. With regard to the lecturer's opinion that the cheque should be more used in India, that was a thing of the very remote future. The idea of the cheque was not common outside Great Britain and America. In France, where he spent the winter of last year, he had the greatest difficulty in getting a cheque for £20 cashed; it took him three weeks to do it in the place he was staying, a remote corner of Provence. The bank opened once a week, on market day, and the manager said he had no advice from Avignon, and that went on for three weeks. If such was the case in France, how very remote must be the contingency in India! The use of a cheque book implied considerable education; a man must at least be able to write his name, and only about 10 per cent. of the Indian population could do that. The difficulty of grafting a co-operative and cheque system on Indian methods, and inducing people to invest their money instead of hoarding it, would be simply enormous. At present their hidden hoards were a great delight to burglars.

THE CHAIRMAN said that before concluding the discussion on Mr. Gubbay's very interesting paper, on which he wished to congratulate him, he should like to make a few comments on it. His knowledge of local banking conditions and practices in India was very limited, and if he ventured to offer some comments—with great

diffidence—it was because of the very clear exposition of these conditions and practices in Mr. Gubbay's paper. His comments were based on these and on the little knowledge he acquired during a brief stay in India two years ago. Mr. Gubbay appeared to be doubtful as to how a central banking system, such as was recommended by the Royal Commission, could be superimposed on the existing indigenous banking system in India. His doubts seemed to be based mainly on two considerations:—

First, the absence in native banking of securities of a character acceptable to an ordinary joint stock bank or to the contemplated Reserve Bank of India, and

Secondly, the difficulty of establishing that touch between the joint stock banks and the native traders which was necessary if the business of the latter was to be brought within the ambit of the general banking machinery of the country working under the control of a central bank.

On the first point, the absence of a security suitable to a joint stock or central bank, he thought Mr. Gubbay was labouring under a misapprehension. He seemed to be under the impression that, for a bill of exchange to become eligible for discount as a true commercial bill, it was indispensable that it should be supported by documentary evidence in the form of sale contracts, invoices, or documents of title of the goods in respect of which the bill had been drawn. It was true that, in the case of overseas bills drawn on London, invoices and shipping documents were attached, but those documents were released as soon as the bill had been accepted. From then onwards the bill circulated without any of those documents to support it. As far as domestic bills in this country, America, and the Continent were concerned, they were usually unaccompanied by any such supporting documents. They were, nevertheless, accepted as true commercial bills fit for discount in the Money Market and at the joint stock banks, and for rediscount at the central bank, if the relations between the drawer and acceptor were such as to satisfy them of the legitimacy of the document as a true commercial bill. The bill of a well established hide merchant and accepted by a well-established tannery firm, for instance, would, in all probability, pass muster without question, even though no documents were tendered. A great many bills in this country, especially those connected with overseas trade, furnished on the face of them quite full particulars of the commodities on which they were based, but there were also bills in this country, but particularly on the Continent of Europe, which were regarded as true commercial bills, even though there was no specific reference in the body of the bill to the transaction on which they were based. A common form on the Continent, for instance, was to simply say, in the body of the bill, that it was drawn in respect of goods. The words usually employed were:—"Value in goods." Yet those bills were freely taken by the banks and rediscounted by the central banks, where they were satisfied, from their general knowledge of the drawer's and acceptor's business, that the bills represented genuine commercial transactions. In the United States, the regulations of the Federal Reserve Board required that a bill tendered to a Federal Reserve Bank should "be drawn so as to evidence the character of the underlying transaction, but if it is not so drawn, evidence of eligibility may consist of a stamp or certificate affixed by the acceptor or drawer in a form satisfactory to the Federal Reserve Bank." In the case of bills which made no reference to the nature of the specific transaction to which they referred, and on which doubts arose in the minds of the discount broker, or banker, who was asked to discount the bill, it was customary for them to make enquiries regarding the circumstances in which the bill had come into being. That information was hardly ever refused, for the good reason that it did not

pay to do so. Unless satisfactory information was furnished in those circumstances, the bill was either not taken or, if taken, only at substantially less favourable rates than would be obtainable for a good commercial bill. When once the trader learned to appreciate that a bill representing an exchange of goods commanded a readier market and a better price, he would probably be most anxious to conform to the requirements of the banker to satisfy him that the bill did truly represent such an exchange of goods. Self-interest would drive him to do so.

That was the experience of other countries, and he did not think that the Indian trader, native banker, or shroff, would be less astute in taking full advantage of such a situation.

The second point was Mr. Gubbay's doubt whether it would be possible to establish that close touch between the joint stock banks and the native banker and trader which was necessary if the business of the latter was to be brought within the ambit of the general banking machinery of the country under the control of a central bank. He understood Mr. Gubbay to say that the business of the Indian community rested almost entirely in the hands of the private native bankers, shroffs, and others, owing to two facts, viz., that

"They are able to give high rates for deposits because they are able to obtain high rates for accommodation granted," and

"They are in intimate daily touch with their clients, whose doings they can follow with a closeness which is denied to the banks."

In so far as high rates for accommodation were justified by the speculative nature of the transaction, they were not likely to appeal to the banks. If the business of the native banker and shroff were confined to transactions of a highly speculative character, the losses which they would unavoidably make from time to time would be sufficient to depress the rates which they could afford to allow to their depositors—if, indeed, the depositors were not frightened away altogether. The assumption seemed to be legitimate, therefore, that a good portion of the business which the native bankers and shroffs do was not really speculative, and needed merely to be cast into a form which would justify more favourable terms and render the business acceptable to the joint stock banks. He saw no good reason why it should not be possible to cast it into such form. When once there was a clearer understanding that certain classes of credit operations were welcomed by the banker, and that they could be carried through on more advantageous terms, the native trading and banking community would not be slow in complying with the requirements of the big joint stock banks. To illustrate this; before the Federal Reserve System was established in the United States in 1914, a bill of exchange was practically an unknown thing in America. Promissory notes (that is, one name paper) were the order of the day. Yet within a comparatively short period of time the community adjusted itself to the new conditions, which was strikingly illustrated by the following figures :—

MILLIONS.			
VOLUME DURING MONTH.			
BILLS DISCOUNTED DURING (Bills discounted for Member banks).	Sept. 1915	Sept. 1916	Sept. 1917
BILLS BOUGHT IN OPEN MARKET (Bankers' and trade acceptances).	14	14	548
	5	37	109
	19	51	657

America entered the war in 1917, and that might have a good deal to do with the sudden increase of bills discounted, bought in that year.

With regard to the channels through which a central bank reached the wider public, and through which it was enabled to exercise its influence in regard to its credit policy, it was clearly what was generally called the money market which constituted that link. A very important element of the Money Market in London was, of course, the money and discount broker. He employed his own capital and the funds which were placed at his disposal, usually by way of call money, to acquire bills of exchange largely from the trading community. To the extent to which his resources permitted he ran the bills, but, if for one reason or another the funds at his disposal were curtailed, he disposed of the bills either by discounting them at a joint stock bank, or, if for reasons of stringency they were not prepared to discount them, he took them to the Bank of England, knowing that the Bank of England was always prepared to discount good bills, which were clearly the result of a true commercial transaction. That knowledge was one of the strongest pillars on which our modern credit organisation rested. The bill broker's business, therefore, was a pretty safe one, provided he conformed to these rules, and the profits he earned depended very largely on his turnover. He constituted one of the most important links between the central bank and the wide public. From the description which Mr. Gubbay gave, the shroff was already performing—it was true, only to a minor extent—those very functions, and therefore was a most valuable nucleus for the establishment of a real money market in India. If he were certain that the joint stock banks were always ready to lend on, or discount, true commercial bills by reason of the fact that the Reserve Bank of India was always prepared to discount them, there did not seem to be any reason to doubt that the shroff whose profit, like that of the bill broker in London, depended on turnover—would seek to acquire such bills wherever they could be obtained. The same remarks, of course, also applied to the small native banker. It would be through these that the influence of the Reserve Bank would reach the bazaars, for it was clearly to the advantage of the shroff and of the small banker to borrow money on the security of good bills, at the more favourable rates of the joint stock banks, rather than to pay high rates for deposit money in the bazaars. That did not, of course, necessarily imply that bazaar rates for business not fit to be undertaken by the joint stock banks would not remain high, but that was a state of things which obtained in every other country. London also had high "bazaar" rates for business that was not eligible for the Money Market or the banks—money-lenders' rates. Mr. Gubbay's paper had made him, if anything, even more optimistic than he was with regard to the possibility of establishing a broad money market in India, and, through it, of establishing a strong link with the joint stock banks and the Reserve Bank of India. He realised that it would take thought, goodwill on the part of the joint stock banks, labour and time, to establish it on a sufficiently broad basis to enable the Central Bank to make its policy felt widely and rapidly. But even if India were less fortunate—as many other countries had been which had established the central banking system—in not possessing so valuable a nucleus for a money market, every effort would have to be made to establish one. He was optimistic enough to think that, if a thing was worth attaining, human ingenuity usually conquered the difficulties and attained it. It would be attained when the ethics of sound modern banking had penetrated into the bazaars. Self-interest would make that penetration an easy one. If India was to expand her banking organisation—and there was a clear consensus of opinion that she must do so if her vast resources were to be adequately exploited—two things were essential: the establishment of a true central bank and of a money market. To attempt to

expand the banking organisation without those would be positively dangerous. The growth of the credit organisation must not be the unco-ordinated growth of the jungle, but an ordered growth—a growth which naturally followed from the growth of confidence in the stability of the organisation. Experience had clearly shown that no credit system could be regarded as safe which did not rest on the centralisation of banking reserves and on the mobility of credit through the bill of exchange. No other system had proved adequate in times of crisis. There was a typical experience in the case of the United States, of which it might truly be said that the credit organisation until 1914 had grown up in jungle fashion, unco-ordinated and unorganised. The violent crises which had shaken the United States at almost regularly recurring intervals had unquestionably retarded the economic progress of that rich continent by decades. If India were unfortunately to be visited by a violent credit crisis, the loss of confidence might set back the clock of banking expansion by a decade or more—not to speak of the stupendous loss it would inflict on her internal economy. The potential wealth of India was immense, and he believed that nothing would help to develop it—and with it to raise the standard of living of the people of India—so rapidly as the establishment of a sound credit system under the protecting wing of a true central bank of issue of the orthodox pattern; but that bank must be organised on lines which would assure its performing its functions without fear or favour, and free from political or sectional influence, in the sole interest of monetary stability, which implied safe and sound credit conditions. He held strong views on this last point, but it was perhaps better not to enlarge on it lest it should add fuel to the fire of controversy in India of recent months. He confessed himself to be an incorrigible optimist both as regards the possibility of India adapting herself to a modern central banking system, and as to the immense benefit the system, if established on orthodox lines, would confer on her. In conclusion he proposed a hearty vote of thanks to Mr. Gubbay for his very instructive paper, and for having thus given an opportunity for an interesting, and fruitful discussion of a very important subject.

SIR REGINALD A. MANT, K.C.I.E., C.S.I. (Chairman of the Indian Section), in moving a hearty vote of thanks to the lecturer and to the Chairman, said the Financial Department of India suffered a great loss when Mr. Gubbay resigned prematurely from the Civil Service, in which he had already made his mark as Controller of Currency and Financial Secretary, and had done his bit in the early part of the war as Wheat Commissioner in mobilising the grain resources of India for the benefit of the allies. When he (the speaker) was in charge of the Department of Revenue and Agriculture problems were continually arising, but it was found that all that had to be done was to carry on on the lines Mr. Gubbay had initiated. He noticed a little note of pessimism at times in the paper, and he could only hope Mr. Gubbay would be inspired with some of the Chairman's optimism, because Sir Henry Strakosch was one of the leading authorities on central banking—the leading authority it might be said. He thought India was very fortunate in securing his services on the Currency Commission.

The motion was carried unanimously.

MR. GUBBAY, in returning thanks, said it was a great pleasure to him to read the paper. He was afraid that there was a tinge of pessimism in it, and there was still a tinge of it in himself in spite of the Chairman's breezy optimism. He would be prepared to maintain his pessimism against the Chairman's optimism, but he did not wish to detain the audience any longer.

THE CHAIRMAN having briefly returned thanks, the meeting then terminated.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, DECEMBER 5. Automobile Engineers, Institution of, at the Merchant Venturers' Technical College, Bristol, 6.45 p.m. Prof. K. C. Browning, "Pinking and Dopes."

Architects, Royal Institute of British, 9 Conduit Street, W. 8 p.m. Business Meeting.

Chadwick Public Lecture, at the Royal Society of Medicine, 1, Wimpole Street, W., 5.15 p.m. Colonel P. S. Lelean, "The Mind and Health."

Chemical Industry, Society of, at Burlington House, W. 8 p.m. Dr. H. S. Hatfield, "Automatic Analysis of Liquids and its Application to Control of Water Softening Plants."

Child-Study Society, at the Central Hall, Westminster, S.W. 6 p.m. Sir Johnston Forbes-Robertson, "The Actors' View of Shakespeare."

Electrical Engineers, Institution of, Savoy Place, W.C. 7 p.m. Mr. N. E. Jackson, "Air Heating and Conditioning."

Engineers, Society of, at Burlington House, W., 6 p.m. Dr. W. Rushton, "The Preservation of the Purity of River Water with regard to Pisciculture."

Farmers' Club, at the Royal United Service Institution, Whitehall, S.W. 5 p.m. Annual Meeting. Mr. Samuel Pulham, "The Trend of Consumers' Requirements for Joints of Meat and how Farmers can supply them."

Geographical Society, at the Æolian Hall, 135, New Bond Street, W. 8.30 p.m. Major J. C. Cooper Clark and Mr. G. Laws, "Lubaantun."

Philologie, Sciences et Beaux-Arts, Société Internationale de, 8, Taviton Street, W.C. 3.30 p.m. Mrs. Hilda Ball, "The Resurrection of Anthony Trollope."

Royal Institution, 21, Albemarle Street, W. 5 p.m. General Meeting.

Surveyors' Institution, 12 Great George Street, Westminster, S.W. 8 p.m. Mr. Lawrence E. Tanner, "Westminster Abbey: Its Royal and Medieval Tombs."

Transport, Institute of, at the Institution of Electrical Engineers, Savoy Place, W.C. 5.30 p.m. Mr. L. C. Harris, "Some Aspects of Shipping Transport."

Victoria Institute, at the Central Hall, Westminster, S.W. 4.30 p.m. Professor Dr. J. A. Menning, F.R.S., "Number in Nature and in the Biblical Literature indicating a Common Origin in a Supreme Intelligence."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Prince D. Svyatopolk Mirsky, "The Russian Novel, 1845-1880." (Lecture IX.)

At King's College, Strand, W.C. 5.30 p.m. Rev. C. F. Rogers, "Ecclesiastical Music." (Lecture IV.) 5.30 p.m. Major-Gen. Sir Frederick Maurice, "Principles of Strategy." (Lecture I.)

At the Royal College of Surgeons, Lincoln's Inn, Fields, W.C. 4 p.m. Mr. F. W. Twort, "The Technique of Bacteriological Research." (Lecture I.)

At the Royal School of Mines, South Kensington, S.W. 5.30 p.m. Prof. Dr. Henry Briggs, "The Ventilation of Mines considered from the Engineering Standpoint." (Lecture I.)

TUESDAY, DECEMBER 6. Anthropological Institute, 52, Upper Bedford Place, W.C. 8.30 p.m. Dr. A. C. Haddon, "Notes on the late R. B. Deacon's Investigations in Nalekula, New Hebrides."

Automobile Engineers, Institution of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 7.45 p.m. Mr. W. A. Whatmough, "Control in Carburation."

Colonial Institute, at the Hotel Victoria, Northumberland Avenue, W.C. 8.30 p.m.

Electrical Engineers, Institution of, at University College, Nottingham. 6.45 p.m. Mr. D. S. Munro, "Modern Electrical Wiring as applied to Small Houses."

Marine Engineers, Institute of, 85-88, The Minories, E. 6.30 p.m. Sir Westcott S. Abell, "The Story of the Ship."

Metals, Institute of, at Armstrong College, Newcastle-on-Tyne, 7.30 p.m. Mr. J. E. Newson, "Hot Extrusion Process."

Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. A. C. Banfield, "Some Odds and Ends from America."

Physiology, London College of, 8, Taviton Street, W.C. 8.15 p.m. Mr. H. J. Harper Roberts, "Modern Scientific Means of Treating Hair Complaints."

Quekett Microscopical Club, 11, Chandos Street, W.C. 7.30 p.m. Dr. H. M. Leake, "Some Aspects of the Plant in relation to Disease."

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Sir William Bragg, "A Year's Work in X-Ray-Crystal Analysis." (Lecture III.)

Transport, Institute of, at the University, Bristol, 5.30 p.m. Mr. G. T. Ryan, "The Working of a Railway Department of a Non-railway-owned Dock." At the Imperial Hotel, Birmingham. 6.30 p.m. Mr. J. A. Dunn, "Transport's true Function."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Sir Bernard Pares, "Russian History to 1861." (Lecture IX.)

At King's College, Strand, W.C. 5.30 p.m. Miss Hilda D. Oakeley, "The Philosophy of Personality." (Lecture IV.)

At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Prof. Dr. Ludwig V. Mises, "Economic Theory and the Social Problem." (Lecture II.)

At the Royal School of Mines, South Kensington, S.W. 5.30 p.m. Prof. Dr. Henry Briggs, "The Ventilation of Mines considered from the Engineering Standpoint." (Lecture II.)

At University College, Gower Street, W.C. 5.15 p.m. Mr. H. Clifford Smith, "The Equipment of a Medieval House."

WEDNESDAY, DECEMBER 7. Analysts, Society of Public at Burlington House, W. 8 p.m. (1) Demonstration of Apparatus: (i) Dr. G. W. Monier-Williams, "Apparatus for Determining Benzoic Acid in Foods." (ii) Messrs. T. McLachlan and A. W. Middleton, "Sodium Flame for Polarimetric Work." (2) Mr. Harold Toms, "Oil Bromide Films and their use in Determining the Halogen Absorption of Oils." (3) Messrs. G. Middleton and F. C. Hymans, "Tests for Impurities in Ether." (i) Dr. Harold J. Stern, "Arsenic in Coated Papers and Boards."

Archæological Institute, at Burlington House, W. 5 p.m. Mr. J. W. Walker, "The Clothing and Arming of the Yeomen of the Guard from 1486 to 1700."

Automobile Engineers, Institution of, at the Belle Vue Hotel, Manchester. 7 p.m. Mr. F. H. Paul, "Design and its Effect on Maintenance Charges."

British Empire Shakespeare Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 3 p.m.

Chemical Engineers, Institution of, at Burlington House, W. 5 p.m. Mr. Norman Swindin, "Submerged Flame Combustion."

Civil Engineers, Institution of, Great George Street, S.W. 6 p.m. Dr. Herbert Lapworth, "The Effect of Pumping Operations on Underground Waters."

Egypt Exploration Society, Burlington House, W. 8.30 p.m. Dr. H. Frankfort, "Akhenaten."

Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m.

At the Cleveland Technical Institute, Middlesbrough. 7 p.m. Mr. H. Paterson, Chairman's Address.

Elizabethan Literary Society, at King's College, Strand, W.C. 8 p.m. Miss Ursula K. Wright, "Nicholas Breton."

Heating and Ventilating Engineers, at Caxton Hall Westminster, S.W. 7 p.m. Mr. W. H. Dupen, "The Comparative Values of Air Treatment as Applied to Ventilation."

Mechanical Engineers, Institution of, at the Liverpool Engineering Society, Liverpool. Mr. Hal Gutteridge, "Modern Portland Cement Plant."

Metals, Institute of, at Thomas' Café, High Street, Swansea. 7 p.m. Mr. R. Genders, "Extrusion."

Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Dr. L. R. Lempriere, "The Health of the Public School Boy."

Tropical Medicine, Royal Society of, 11, Chandos Street, Cavendish Square, W. 8.15 p.m.

University of London, at Bedford College, Regent's Park, N.W. 5.15 p.m. Prof. Mary W. Calkins,

"Conceptions of Meaning and of Value." (Lecture I.)

At the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. Dragutin Subotić, "Serbo-Croat Medieval Literature." (Lecture II.)

At King's College, Strand, W.C. 5.30 p.m. Dr. Ernest Barker, "The University and the University College."

At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Demonstration of the Telephone by Mr. R. Sioley.

At the Royal College of Surgeons, Lincoln's Inn Fields, W.C. 4 p.m. Mr. F. W. Twort, "The Technique of Bacteriological Research." (Lecture II.)

At the Royal School of Mines, South Kensington, S.W. 5.30 p.m. Prof. Dr. Henry Briggs, "The Ventilation of Mines considered from the Engineering Standpoint." (Lecture III.)

At University College, Gower Street, W.C. 3 p.m. Dr. C. Pellizzi, "La Lirica del Paradiso" (in Italian). (Lecture II.)

5.30 p.m. The Hon. Mr. Justice McCauley, "Case Law."

THURSDAY, DECEMBER 8. Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 3.30 p.m.

Chemical Engineers, Institution of, at Burlington House, W. 5 p.m. and 8 p.m. (a) Mr. G. W. Daniels, "The Design of Refrigerating Plants." (b) Mr. Leccig Chew, "The Practical Aspects of Refrigeration as Applied to the Chemical Industry." (c) Mr. Raymond Mitchell, "Electrical Automatic Refrigerators for Domestic Use."

Electrical Engineers, Institution of, at University College, Dundee. 7.30 p.m. Mr. R. J. Lawson, "A Description of Modern Telegraphs."

Historical Society, 22, Russell Square, W.C. 5 p.m. Messrs. E. A. Whitney and P. P. Cram, "Polydore Vergil's Will."

L.C.C. The Geffrye Museum, Kingsland Road, E. 7.30 p.m. Captain E. W. Gregory, "The Furniture of William Kent."

Mechanical Engineers, Institution of, at the Hotel Metropole, Leeds. 7.30 p.m. Mr. John H. Barker, Chairman's Address.

At Bristol, Mr. W. A. Stanier, Chairman's Address.

Metals, Institute of, at 83, Pall Mall, S.W. 7.30 p.m. Mr. W. A. C. Newman, "Strip Casting." (Joint Meeting with the Institute of British Foundrymen.)

Oil and Colour Chemists' Association, at 8, St. Martin's Place, W.C. Dr. G. Shearer, "The Application of X-Rays to Industry."

Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. F. J. Tritton, Demonstration of Three-Colour Carbro.

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Mr. J. Kewley, "Petroleum Natural Gases and their Derivatives."

Tropical Medicine, Royal Society of, 11 Chandos Street, W. 7.45 p.m. Dr. William Fletcher, "Recent Work on some Malayan Fevers."

University of London, at Bedford College for Women, Regent's Park, N.W. 4.15 p.m. Prof. Eccles, "Voltaire: les meilleurs moments et les plus belles pages." (Lecture X.)

At the Imperial College of Science, South Kensington, S.W. 5.45 p.m. Mr. R. H. Fowler, "Statistical Mechanics, Old and New." (Lecture III.)

At King's College, Strand, W.C. 5.15 p.m. Dr. F. J. C. Hearnshaw, "Lord Bolingbroke."

5.30 p.m. Baron A. F. Meyendorff, "The Crisis of Communism." (Lecture II.)

At the Royal School of Mines, South Kensington, S.W. 5.30 p.m. Prof. Dr. Henry Briggs, "The Ventilation of Mines considered from the Engineering Standpoint." (Lecture IV.)

At University College, Gower Street, W.C. 5.30 p.m. Miss E. Jeffries Davis, "London Place-Names." (Lecture V.)

5.15 p.m. Prof. de Montmorency, "Customary Law in the British Empire." (Lecture VI.)

Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Mr. H. Clifford-Smith, "Jewellery in Pictures."

Wireless Technology, Institute of, at the Engineers' Club, Coventry Street, W. 7 p.m. Mr. W. A. Chambers, "Mains Operation of Receivers."

FRIDAY, DECEMBER 9. Chemical Engineers, Institution of, at Burlington House, W. 5 p.m. and 8 p.m. Mr. W. J. Jones, "The Problem of Industrial Lighting with some reference to the Chemical Industry." Messrs. R. G. Parker, D. N. Jackman and J. N. Vowler, "Continuous Weighing of the Contents of Vessels: The Weighmeter." Mr. A. T. Green, "The Properties of Silica and Fireclay Refractories in Relation to their Industrial Usage."

Dyers and Colourists, Society of, at Milton Hall, Deansgate, Manchester. 7.30 p.m. Mr. W. E. Sandersen, "The Colouring of Cold Cured Rubber."

Engineering Inspection, Institution of, at the Royal Society of Arts, Adelphi, W.C. 7.30 p.m. Messrs. F. R. Wade and C. H. Parker, "Low Temperature Distillation of Coal."

Mechanical Engineers, Institution of, Storey's Gate, S.W. 7 p.m. Major S. J. Thompson, "Economics in Engineering."

Metals, Institute of, at the University, St. George's Square, Sheffield. 7.30 p.m. Prof. Dr. C. H. Desch, "Stresses in Non-Ferrous Castings."

North East Coast Institution of Engineers and Shipbuilders, Bolbec Hall, Newcastle-upon-Tyne. 6 p.m. Mr. C. W. Cairns, "The Relation between Drawing Office and Shipyard and Engine Works."

Philologie, Sciences et Beaux-Arts, Société Internationale de. 8.15 p.m. Dr. H. M. Leon, "The Faust Legend—Its Origin, History and Development."

Physical Society, at the Imperial College of Science, South Kensington, S.W. 5 p.m. (1) Mr. H. P. Walmesley, "The Scattering of Light by Individual Particles in Smokes." (2) Mr. J. J. Manley, "On the Construction and Standardisation of an Interferometer Pressure Gauge."

Transport, Institute of, at the Town Hall, Newcastle-upon-Tyne. 5 p.m. Paper by Mr. Richard Aughton.

University of London, at Bedford College, Regent's Park, N.W. 5.15 p.m. Prof. Mary W. Calkins, "Conceptions of Meaning and of Value." (Lecture II.)

At the Royal College of Surgeons, Lincoln's Inn Fields, W.C. 4 p.m. Mr. F. W. Twort, "The Technique of Bacteriological Research." (Lecture III.)

SATURDAY, DECEMBER 10. L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Miss M. A. Murray, "The Legacy of Egypt."

Mathematical Association, at Bedford College, Regent's Park, N.W. 3 p.m. Mr. F. C. Boon, "A Mathematical Course for Post-Matriculation Non-Specialists."

Royal Institution, 21, Albemarle Street, W. 3 p.m. Mr. F. J. M. Stratton, "Recent Developments in Astro-physics."

JOURNAL OF THE ROYAL SOCIETY OF ARTS

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VOL. LXXVI.

FRIDAY, DECEMBER 9th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK.

WEDNESDAY, DECEMBER 14th, at 8 p.m. (Ordinary Meeting). MAJOR RAYMOND G. H. CLEMENTS, M.C., M.Inst.C.E., "The Evolution of Modern Road Surfaces." SIR FRANK BAINES, C.V.O., C.B.E., will preside.

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FIFTH LIST OF SUBSCRIPTIONS.*

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The Council are extremely anxious to secure a generous response to the Prime Minister's Appeal, and they earnestly beg all those who have any feeling for the charm of the English countryside to subscribe to the Fund and to do what they can to interest their friends in the movement. Every day beautiful old cottages are being threatened with demolition, and unless help is speedily forthcoming many will be lost for ever.

A second edition of Mr. Baldwin's Appeal on behalf of the Fund has just been issued as an illustrated pamphlet, and the Secretary will be glad to send copies to all who apply for them. It contains photographs and short accounts of Charles Lamb's Cottage in Hertfordshire, and the Thomas à Becket Cottages near Worthing, which have lately been saved by the Society.

DR. MANN JUVENILE LECTURES.

Under the Dr. Mann Trust, PROFESSOR ARTHUR SMITHELLS, C.M.G., D.Sc., F.R.S., Director, Salter's Institute of Industrial Chemistry, will give two lectures for children on "Flame," at 3 p.m. on Wednesday, January 4th and 11th. The lectures will be fully illustrated by experiments.

Special tickets are required for these lectures. A sufficient number to fill the room will be issued to Fellows in the order in which applications are received, and the issue will then be discontinued. Subject to these conditions, each Fellow is entitled to one ticket admitting two children and one adult. Fellows who desire tickets are requested to apply to the Secretary at once.

The syllabus of the lectures was published in the *Journal* dated December 2nd.

FIFTH ORDINARY MEETING.

WEDNESDAY, NOVEMBER 30th, 1927. HIS EXCELLENCY THE FRENCH AMBASSADOR, M. DE FLEURIAU, Commandeur Légion d'Honneur, G.C.V.O., in the Chair.

A paper on "Marcellin Berthelot and Synthetic Chemistry," was read by PROFESSOR HENRY E. ARMSTRONG, LL.D., Ph.D., F.R.S. The paper and discussion will be published in an early issue of the *Journal*.

CANTOR LECTURES.

MONDAY, DECEMBER 5th, 1927. PROFESSOR H. C. H. CARPENTER, M.A., A.R.S.M., F.R.S., Professor of Metallurgy, Imperial College of Science and Technology, delivered the last of his course of four lectures on "Alloy Steels, their Manufacture, Properties, and Uses." A vote of thanks was accorded to Professor Carpenter for his interesting and instructive course.

The lectures will be published in the *Journal* during the Christmas recess.

PROCEEDINGS OF THE SOCIETY.

THIRD ORDINARY MEETING.

WEDNESDAY, NOVEMBER 16th, 1927.

THE RIGHT HON. LORD DAWSON OF PENN, G.C.V.O., K.C.B., K.C.M.G., M.D., D.C.L., in the Chair.

THE CHAIRMAN said it was his pleasant duty to introduce Professor Leonard Hill—a former colleague of his, and always an inspiring companion. The subject of the lecture was one which Professor Hill had made his own. It had been a habit of the lecturer's distinguished career not only to seek out knowledge for its own sake but to apply it to the public good. The public's gratitude to him was not confined to his researches on respiration; his range of work had been much wider, and he had added to existing knowledge in a great many directions. Professor Hill's researches on blood pressure had been in a large measure responsible for the further study of blood pressure and its application to medical practice, which had been a great achievement and of considerable assistance in the curing of the sick; in fact he (the Chairman) thought it might be said that Professor Hill had almost given them too much of a good thing, because at the present day blood pressure, from being a useful adjunct in the investigation of disease, was developing almost into a craze which was producing public alarm.

Returning to the subject of the lecture, he was sure Professor Hill would proceed to let in both light and air. The lecturer stood forth as a doctor who practised what he preached. The last occasion on which he had had the pleasure of seeing him had been on a Norfolk road, when the Professor had been lightly clad, his head the colour of mahogany, and looking the picture of health. He had noticed

on that occasion that the Professor was wearing a red tie, and he had never been able to discover whether that tie had served some physiological purpose or had merely illustrated a political trend! If the lecture would do no more than help to get rid of that mischievous expression "catching cold" it would do a great public service; but it would do far more than that, and he would now give the audience an opportunity of discovering that fact.

The following paper was then read:—

OVERCROWDING IN PUBLIC CONVEYANCES.

By PROFESSOR LEONARD HILL, M.B., F.R.S., HON. A.R.I.B.A.

The question regarding the influence of crowded public conveyances on health is one which is largely bound up with the traditional fear of exposure to cold. The public conveyance ought to offer those who are confined in sedentary occupations in stagnant warm air, an invigorating blow and exposure to sunlight while going to and from their work, but governed by traditional fears, most people demand shut up and artificially heated cars, and regard those of us who enjoy exposure to wind and sun as 'open air fiends.' The clever posters of the tube railways direct attention to scenes of snow, lightning, rain and fog in the streets, and exhibit the warm comfort of bright artificial light on the underground trains. A very moderate degree of warmth, dryness, good ventilation, an artificial light giving the ultra-violet rays present in sunlight, and no overcrowding, are very desirable conditions, and everything should be done to see that all these conditions are attained.

Most of us are so accustomed to sheltered lives, to warm clothing, draughtless houses, central heating, etc., and so brought up in a traditional fear of cold, that it is difficult to realise how resistant man naturally is to exposure to cold. Darwin, in the *Voyage of the Beagle*, told us of the native Fuegians, naked in a climate more inclement than ours, and sleeping like hares in forms under brushwood; and so resistant are these people to exposure that they have to commit infanticide to keep the population down to the food supply. Mme. David Neel has recently described * the course of training undergone by students of the lamas in Thibet. After a long period of probation, designed to weed out the weakly ones, they come to renounce all woollen and fur clothing and never approach a fire. They finally have to pass a test of sitting naked upon the ground cross-legged on a windy, frosty, and moonlight night. Sheets are dipped in icy water and each man wraps himself in one and remains motionless until the divine internal heat of his body has dried the sheet, which is then dipped in the water and again wrapped round him, and so on throughout the night. The student who has dried most sheets is the winner. To qualify in this test three sheets must be dried. Natives of Eastern Tibet and hermits of the Himalayas thus train themselves to live naked except for a thin cotton

* *Daily Mirror*, October 10, 1927.

garment. Mme. David Neel says that she has achieved very passable results in this seemingly impossible accomplishment. We know that warmly clad fishermen and arctic travellers endure with impunity the severest conditions of exposure, so too soldiers in the Great War; men taken from factory, shop and office, and trained for some months and then exposed in wintry trenches and dugouts. Under such conditions catarrhs are not prevalent, but almost absent. The open air removes the danger of microbic infection and the irritation of house dust from the respiratory membrane, and stimulates body heat production, the tone of muscles, the appetite, etc.

We need to realise that the open air life makes us healthy, happy and vigorous, and that life spent too much in stagnant heated conditions brings on the very troubles which people mistakenly try to avoid by such conditions. We have to do our sedentary work indoors, with some artificial heat for comfort's sake, but the heating should be minimal, and the ventilation maximal, and open air exercise should be regularly taken to counteract the ill effects of confined sedentary life. As much as possible the journey to and from business should be taken in the open air. I have studied records from places widely apart as Manchester, England, Leysin in the Alps, San Francisco in U.S.A., or Durban in South Africa which show that children who are put to live open air lives with no artificial heating suffer very little or not at all from catarrhs and infective fevers. These complaints are the results of crowding indoors with massive infection and reduction of immunity through ill-chosen food and bad atmospheric environment. The Chief Medical Officer of Natal told me that the Zulus who go naked except for some beads do not suffer from catarrhal respiratory diseases. These diseases are prevalent in the clothed Kaffirs in districts adjoining Zululand.

As a recently published example* of the effect of the open air school I cite Greengate school in Manchester, which consists of a large shed always open on the south side, with large unclosable "louvre" ventilators on the north side, so that there is a free and constant through current of air. There was no ordinary heating apparatus but arrangements were made for drying clothes and blankets. During winter the temperature of the open air often remained between 40° and 45°F. for several weeks, occasionally falling to freezing point. During the day the children either slept without overhead cover in the open air, or under cover of the lofty roof of the open shed. "Some of the smallest children at first complained of the cold, and sat huddled up like little dormice too sleepy to work." Additional clothes and rugs were therefore at first provided, the rest times lengthened and hot milk given in the middle of the morning. In 3 or 4 weeks, often less, the children became acclimatised, and towards the end of the term, although the temperature was then only one degree above freezing point, they scorned the blankets and asked to be allowed to discard their overcoats.

**Healthy Growth*, by Mumford.

Their breathing became deeper, their complexions improved, catarrhs and feverish attacks lessened and disappeared. Their nerve energy increased, their muscles gained in tone, and their rickety bones took on the proper shape. Their body growth accelerated and their school work improved. The children were able to pay closer attention and concentrate for longer periods on their lessons.

In the town of Durban (S. Africa) the Chief Medical Officer of Health for Natal, Dr. Park Ross, tells me that he combats the debilitating effects of a warm moist climate by getting people to go in for sea bathing each evening (some 5,000 do this), and by the free use of electric fans in factories, schools and houses. These have to be ventilated so that the proper standard of kata thermometer cooling powers as given by me are obtained. This is found very advantageous. The blowing of air by fan or duct upon the back of the neck may produce signs of catarrh or sore throat, but blowing on the face never does this, even though the wind be so great as just not to move the papers on a desk ; the blowing of air on the head and face is of great advantage in the warm humid climate of Durban through the enhanced cooling and evaporative effect. We know in our climate that when the body is set in unison with a warm atmosphere it is certainly unpleasant and reputed to be productive of catarrh to have a draught impinging on and chilling one part of the body. I have some evidence that wind blowing on the face sets the lining membrane of the nose and throat in the right condition of circulation and secretion, etc., to resist infection. At night Dr. Ross says it is quite safe to set a fan to cool the lower parts of the legs and feet, and so secure comfort when sleeping in the warm climate of Durban, but it is not wise to sleep with a fan blowing on the trunk. Cool breezes blowing round the head, the radiant heat of the sun, and a warm ground to stand on, are the ideal outdoor conditions. The healthy mucous membrane of the nose, examined by aid of a speculum under these conditions appears pale and taut. If touched with a probe it does not pit, and there is no thick secretion upon it. Indoors when the feet are chilled by a cold draughty floor, and the head is immersed in warm stagnant air, the nasal membrane appears swollen, congested, and covered with thick secretion and pits when probed. Given a deflected septum, the nose on one side shuts up under such conditions, to open again when the feet are warmed and the head cooled. It is this congestion of the sinuses of the nose which causes the feeling of stuffiness in the head in crowded rooms, not any chemical impurity of the air. Suppose the nasal membrane to be so swollen and congested, then on going into cold outside air it becomes pale owing to vaso constriction, but for some little time remains swollen and boggy and covered with secretion. In crowded rooms infection takes place from 'droplets' of mucus sprayed out when sneezing, coughing, or speaking in a spluttering way. A membrane covered with thick secretion, swollen and congested may offer possibly a medium more suitable for infection than one which is taut and well supplied with arterial blood lymph and secre-

tion. Stagnant, congested conditions of the nose and its sinuses may in unhealthy people possibly exalt the virulence of those microbes which cause catarrhs, and so spread infections. Almroth Wright has shown how the outflow of lymph in a wound washes away, and keeps down the growth of microbes. Antiseptics, poultices, ultra-violet rays etc., act not by directly killing microbes but by increasing the outflow of phagocytes and lymph, and the defensive reaction of the tissues. The mucus secretion and the ceaseless cleansing sweep of the cilia form the defence of the respiratory membrane of the air tubes, while the outflow of lymph and the phagocytes defend the alveoli of the lungs. Dust, microbes and viruses are cleaned away by these defences which must be maintained in vigorous condition by suitable food and atmospheric environment. Where the cilia are killed by some poisonous fume or dust, microbes may infect and bronchitis result. Of great importance to our defence against catarrhal infection must be the rate of evaporation from the lining membranes of the nose, throat, and breathing tubes of the lungs and from the conjunctival membrane of the eyes, and the flow of blood and lymph through these membranes which is required to maintain the secretion of fluid which evaporates, and to keep the membranes near body temperature. The breathing of cool open air during the night, and the taking of vigorous open air exercise during some part of the day, and the avoidance of the stagnant warm moist air of crowded places has a great effect on maintaining the flow of secretion from and the flow of lymph and blood through these membranes.

W_0 is the weight in grammes of water vapour in a volume x litres of air inspired and W_1 the weight present in the expired air, then the weight of water evaporated by the respiratory passages is given by

$$W_1 - W_0 = x \times 1.293 \times 0.625 \times \frac{273}{273 + t_0} \times \frac{p_1 - p_0}{760}$$

where p_0 is the vapour pressure of the water vapour in the inspired air, p_1 that of the water vapour in the expired air, t_0 the centigrade temperature of the inspired air, 1.293 is the weight of a litre of dry air at freezing point and 760 mm. pressure and 0.625 is the specific heat of water vapour referred to air at the same pressure and temperature. Observation shows in different atmospheric conditions that with remarkable constancy 33°C is the wet bulb temperature of the expired air; the maximum vapour pressure at 33°C is 37.43 mm. Hg. The air breathed by a sedentary man may be taken as 10 cubic metres per diem. With a dry bulb 4.4°C . (40°F .) wet bulb 2.5°C (36.5°F .) and dew point 0°C ., he will then evaporate from his breathing passages 344 gm. of water; suppose, on the other hand, in a warm humid atmosphere the dry bulb is 21.7°C (71°F .) wet bulb 20.5°C . (69°F .) and dew point 20°C he will evaporate only 198 gm. of water. The increased breathing produced by much active exercise may double these daily outputs of evaporated water. On a cold day then out of doors with vigorous exercise by day, and sleeping by night on a verandah out of doors the

evaporation might be 688 gm. of water per diem against 198 gm., for the sedentary life spent indoors with dew point 20°C. While 600 calories of heat are lost in the evaporation of each gm. of water, the air breathed in is also warmed (or cooled if the outside air is hot) and expired at about 34-37°C. During hard exercise cold air may be warmed to 37°C and the temperature of the membranes of the nose, throat etc., raised to this point. Such rise in temperature together with the greater flow of blood lymph and secretion occasioned may be of value in resisting infection. The ciliated epithelium works more actively in sweeping up microbes and dust at the higher temperature, and the phagocytic action of leucocytes is increased. While the density of dry air is approximately 0.0013, the specific heat is 0.24. The heat spent in warming up the inspired air then in the first case, viz., that of open air life with exercise is given by

$$\frac{20,000,000}{1,000} \times \frac{273}{277.4} \times 0.013 \times 0.24 \times 30.6 = 187 \text{ Cal., the rise of tempera-}$$

ture of the air breathed being taken as 35 - 4.4 = 30.6°C. and the amount breathed as 20 cm. = 20,000,000 c.c. In the other case, viz the sedentary

$$\text{indoor life we have } \frac{10,000,000}{1,000} \times \frac{273}{294.7} \times 0.0013 \times 0.24 \times 13.3 = 38 \text{ Cal.}$$

The rise of temperature of the air breathed being taken as 35 - 21.7 = 13.3°C and the amount breathed as 10 c.m. = 10,000,000 c.c. The heat lost by evaporation in the first case is 688 × .6 = 412.8 Cal. and in the other case 198 × .6 = 118.8. The total loss from the breathing membranes by evaporation and warming the air is in the one case 412.8 + 187 = 599.8 Cal. and in the other 118.8 + 38 = 156.8 Cal. In other words, in the outdoor conditions, with exercise, a heat loss almost four times greater than in indoor conditions has to be, and is, made good in the breathing passages by the flow of arterial blood lymph and secretion in order to keep up the temperature, while the amount of water evaporated is 3½ times greater. Observation shows that more water may be secreted than is evaporated when one faces a cold wind; the eyes and nose then water freely. * The mucus membrane is thus in the outdoor conditions far more thoroughly swept with arterial blood and washed with secretion, and thus defended from infection. High cooling power of the cold moving air acting upon the face has to be made good by a greater flow of arterial blood and secretion and the sinuses of the nose benefit and their resistance to microbic infection increased. There exists in the lung a comparatively vigorous lymph production and drainage by lymphatics and the respiratory movements aid in evacuating the lymphatic vessels and particularly so during vigorous exercise. The assistance given to this lymph flow in the case of a sedentary person in a warm humid indoor atmosphere will be less, while dust pollution and infection are greater.

We know that exposure of the naked body of children to sun and open air, whenever the weather allows this to be done, has a wonderful curative effect on states of debility, rickets and surgical tuberculosis. Argyll Campbell and I found that such exposure puts up the daily metabolism of children lying splinted and at rest 40 to 100 per cent. above that of children living an ordinary city life. We know that thousands of clerks, shop assistants, and factory hands taken from lives spent in monotonous over-warm places, were changed from feebly developed, nervous dyspeptic men into strong healthy soldiers by training in the open air and sunshine and hard exercise during the Great War. The increase of metabolism and heat production by exposure to cold increases the muscle tone, the depth of ventilation of the lungs, and the circulation of the blood, and ensures the absorption, and utilisation of food, while the deeper respiration and greater muscular activity naturally massage the abdominal viscera and prevent constipation, etc. There is, then, every indication of need for good ventilation and some exposure each day to open air conditions. As a test of ventilation, the ordinary thermometer fails, for it merely indicates the average effect of the temperature of the environment upon itself. Unlike the human body, it does not produce heat. If a fan is set to blow upon it in a room at 65°F. the reading does not alter. The body, on the other hand, is very effectually cooled by the fan in such a room; the thermometer is then an untrustworthy guide to ventilation. The kata-thermometer was introduced by me to remedy its defects. This instrument has a bulb which is warmed above 100°F. and the rate of cooling is measured during the drop between 100 and 95°F. A factor is determined by the maker for each instrument by means of which the cooling power of the air acting on the surface of the "kata" bulb at approximately skin temperature is measured in mille calories per sq. cm. per second. The kata thermometer can be used dry, or wet, in this case covered with a muslin net. The wet "kata" is comparable with the sweating skin. The bulb of the instrument is about the size of the end joint of the thumb. The big masses of the body are cooled much less rapidly than this, having a far smaller surface exposure in proportion to volume. The "kata" does not then actually measure the cooling effect of the air on the body, but empirically graduated it is a valuable indicator of comfortable and invigorating conditions. In rooms kept fresh and warm enough for sedentary work the cooling powers are found to be about 6 dry and 18 wet "kata." In stuffy rooms the figures are lower, e.g., 4 dry and 14 wet. In cool fresh rooms, e.g., a sanatorium ward, readings of 10 dry and 25 wet are found and so on. Out of doors where the wind blows the cooling powers are higher; for example, dry "kata" 10 on a genial summer day, 20 in a cool breeze, 40 in a cold winter wind. The open air worker is stimulated by much higher cooling powers than the sedentary worker owing mostly to the movement of the air. Observation has shown us that to increase the heat production of the body when resting in ordinary

clothing, a cooling power of the dry "kata" of 14 or over is required. With less cooling power the body compensates for the cooling effect by regulating heat loss by vaso-constriction of the skin and lessened convection and evaporation. As a very large part of the energy of the food is spent in maintaining body heat an adequate cooling power is required to keep the "fire of life" burning well.

Mistakenly attributing the origin of catarrhal complaints and pneumonia to exposure to cold, people have demanded and procured excessive heating, not only of offices, factories, etc., but of railway trains with the shutting up of windows, the closing in of the roof seats of trams and now of buses. For escaping exposure to wet the roofing in of buses and trams is reasonable and advantageous for people who cannot protect themselves with coats or waterproofs; and the bus companies have found in London that people desert the open top of a bus for the tube railway in inclement weather. Therefore for the sake of profit they are compelled to close them in and provide what the public demand.

It is a pity, for the open outside of a bus affords those who do not possess a car all the good which a blow in an open car gives. People should try more to adapt their clothing to conditions and live as much as possible an open air life, and enjoy the splendid results which debilitated children enjoy when taken away from city homes and given open air treatment at sanatoria. The methods found so effective in curing ill conditions set up by confined life in cities should be used to prevent such conditions arising. The man who has been cured of pulmonary tuberculosis by open air treatment rejoices in a cold wind and loves to feel it sweep through his clothing and incite him to take vigorous exercise, and so keep warm by increased body heat production. He puts on no hat, overcoat or muffler, has no fear of exercise in night air or rain but changes his wet things after his exercise. He rides in an open car in winter, then of course adequately clad, and all the year round sleeps by an open window. He regards cold as a friend and energiser of bodily health, vigour and appetite, given of course, the money to buy the extra food he needs for fuel in his body. No one wishes to sit still in a cold wind or in wet clothes till chilled and shivering with discomfort, or in a warm room with skin flushed and moist and a cold draught playing on one part of his body, but people must put away the over fear of draught which possessed the upper classes of the Victorian age, such as are so well portrayed in Miss Austin's "Emma," and should try on every occasion to secure the maximal movement of the air compatible with comfort, and put on more clothing rather than shut windows so as to secure the great good of breathing clean cool open-air. Pollution of the air with dust and fumes poisonous to the living cells of the respiratory membrane, and infection with microbes of catarrhal diseases are the great causes of these complaints, not draughts or exposure to cold. The scientific evidence is very strong in favour of this view, and very much against the commonly accepted opinion. Just as malaria was attributed to a miasm and proved to be due to

an infection, spread by mosquitoes, so catarrhal complaints and pneumonia are attributed to exposure to cold and are really due to irritation by dust, microbic infection and lowered resistance of the mucus membranes caused by ill diet and stagnant air. The infection is spread by 'carriers' in crowded stagnant air by 'droplets' of saliva explosively scattered in sneezing, coughing and speaking. The importance of carriers is shown by the epidemics of catarrhal diseases which arise in far outlying islands each time an annual visit is made by a ship. Arctic explorers frightfully exposed to weather, have suffered from no catarrhal complaints, saving the exception when some bale of clothing was opened which was packed in London and carried an infecting dust. Catarrhal infections can be spread by carriers who are not ill. Thus poliomyelitis, which starts as a catarrhal infection, is spread by carriers who have no signs of illness, e.g., a farmer leaving his child ill with the disease travelled 20 miles and sat at dinner between two children. Within 48 hours both of these were taken ill with the disease. It is known that virulent types of pneumonia may spread by infection from house to house in small villages. The catarrhal complaints, such as influenza, appear to be started by a "filter-passing" virus which produces a three day fever and leaves the body weakened in defence against the invasion of secondary infections such as are caused by pneumococci, streptococci etc., which are commonly present in the nose and throat of people, and against which we are usually immune through vaccination with small doses. It is not possible by leading healthy lives to prevent the spread of such virus infections among people who crowd indoors but it is possible to keep down dangerous secondary infections. These result from ill feeding and crowding in shut up dwellings and cause a high mortality. There is ample evidence that many people are vaccinated by small doses of infective fevers where there is adequate ventilation; they then have the mildest of attacks often unrecognised which protects them. There is also abundant evidence that people fall victims to serious infective illness where there is crowding, ill feeding and a confined life. It is clear also that people are 'unsalted' when living an open-air life, and are prone to serious infective disease when coming to a city. Crowded sleeping decks on board such a training ship as the "Impregnable" cause a very high rate of morbidity. How such morbidity may be lowered by introduction of hygienic methods, spacing out etc., has been shown by Surgeon Commander Dudley.*

Crowding in closely packed tenements reacts most unfavourably on child life, producing a high incidence of those respiratory diseases which depend on close contact for their dissemination. Thus, measles is most severe and fatal through the complication of broncho-pneumonia in such crowded tenements. For example, Dr. McGregor, Medical Officer of Health of Glasgow, has cited the following figures for that city: -

*Spec. Rep. Ser. Med. Res. Council, 1926. No. 111.

	Residential Wards.	Mainly industrial Wards.	Industrial and poor Wards.
Total infant mortality per 1,000 births	40-60	100-120	120-140
Due to respiratory diseases	3.7	18.7	23.0

A diet deficient in the anti-rachitic vitamin D, (which we now know to be produced by the action of ultra-violet rays of the sun on ergosterol in the skin or in foods) and of the other vitamins A, B and C, contributes greatly to lessened resistance to infection.

Cold weather increases deaths from respiratory diseases because it causes children to be kept indoors in stuffy over-heated rooms where dust pollution and infection are intensified and health weakened by heat stagnation, lowered metabolism and want of sunlight.

Captain Douglas and I sprayed a weighed quantity of a culture of harmless microbes into a room, and exposing culture plates 5 and 10 minutes later (for 2 minutes) recorded the number of colonies which grew. We found then an open window or a fan very greatly lessened the number of colonies. If guinea pigs are kept in cages in a closed room close to an active coughing case of phthisis, these animals become infected with tuberculosis. Put further off fewer are infected; with open window very few, if any, are infected. At the Papworth open colony the young children reside with their parents, and under the open air conditions none are attacked by tuberculosis. In crowded tenements the infection spread to children by consumptive parents is disastrous.

Storm van Leeuwen has produced evidence to show that certain water-soluble products of common moulds present in house dust provoke bronchitis and asthma.

All the evidence then goes to show that public conveyances should be kept as free from overcrowding and as well ventilated as possible, so as to avoid dust and infection with large doses of the catarrhal viruses. If some terrible type of catarrhal disease such as poliomyelitis, or encephalitis lethargica, should start in serious epidemic form, there would arise very great danger from crowded conveyances and public meeting places. We have no security that at any time a devastating epidemic of such disease may not arise. In fact probability favours the occurrence of such epidemics which have affected cities in Europe and America. In the open air, where the wind blows as it listeth, in rooms swept with air currents by fans, in carriages with windows open, in open buses, massive infection by carriers is not possible. In a shut up railway compartment when an acute case of catarrh is sneezing, some protection from massive infection possibly may be gained by a newspaper held in front of the face. The droplets will be caught and the infection held by that (until dried and spread as dust). If people in an acute stage of catarrh cannot stay at home as they should, custom should make them protect their neighbours by sneezing and coughing into handkerchiefs, and holding a newspaper in front of their

faces when speaking. The trouble, however, is that the virus infections are spread by those who are not obviously ill and against such spread good ventilation can alone be effectual. This knowledge has been taught now for some years, but it does not reach the general public. People generally continue to fear cold unreasonably, and shut up windows, and look for a nostrum to stop catarrhal complaints.

A study has been made of the ventilation of public conveyances.

Investigations of the Central Tube Railway air by Andrewes, 1902, and underground electric railways by Graham Forbes, 1920, afford evidence of no really gross microbic air pollution. The mean of the results of organisms growing at 20° C. reduced to the same proportion per litre is about 9 per litre for the railways and 6 for outside air. In 28 naturally ventilated schools, described as very dirty, a mean of 152 per litre was obtained by Carnelly, Haldane and Anderson (1887), and 3 per litre in good class mechanically ventilated institutions. The air of one-roomed houses averaged 60 per litre, two roomed 46, and four or more roomed 9. In the Debating Chamber of the House of Commons the mean was 6, and 32 in the Committee, Dining and Smoking rooms (Graham Smith, 1902).

Soper (1908) concluded from chemical and bacteriological analyses of the air in New York subways that the conditions were satisfactory, and that the exchange of air was abundant except in closed and crowded cars and where dense crowding on platforms occurred. The high temperature of the subways was the most objectionable feature.

* Graham Forbes' (1920) conclusion was that with the existing ventilating arrangements for certain of the carriages and tubes in London, the crowding of passengers may be prejudicial in epidemic times.

We know that in crowded ill-ventilated rooms the chemical impurity of the air, so far as concerns diminution of oxygen, increase of carbonic acid, or any organic chemical poison supposed to be inhaled, is not significant. The oxygen percentage in the depths of the lungs is about 14½, and the carbonic acid about 5, and the breathing mechanism is so controlled as to keep these figures constant, and the small rise of carbonic acid percentage and fall of oxygen percentage in crowded rooms (at most about 0.5 per cent.) has then no effect. It is only in high altitudes that any want of oxygen comes into play, or in places such as submarines and mines where natural ventilation, in absence of chinks and crannies, cannot take place.

When all visible chinks are closed in a room a fire burns no less well and some 20,000 c.ft. of air an hour continues to pass up the chimney. In a dugout of 900 c.ft. capacity, containing 30 soldiers and three candles alight, I found that natural ventilation on a cold day maintained a flow of air ample enough to secure chemical purity in spite of double anti-gas curtains set to block the two exits. T. Crowder estimated that there is a sum total of about 500 lineal

* Graham Forbes, *J. of Hygiene*, 22, 9, 1924.

feet of crevices at the edges of doors and windows in a sleeping railway car. If these averaged one-fiftieth of an inch in width and admitted air at half the rate of the train speed, 40,000 c.ft. of ventilation would be more than accounted for.

So long as there is a temperature difference between the air inside and outside a room natural ventilation takes place through every chink and cranny, the warmer more humid inside air rising and the colder heavier outside air sinking in. Wind blowing in through crannies greatly increases this ventilation. The change of air per hour in a room occupied by people can be determined by estimating the carbonic acid in the air of the room, the air supply being inversely as the increase of carbonic acid due to respiration.

$$A = \frac{VP}{X - N}$$

where V = the CO₂ produced by one person in c.ft. per hour

P = the number of people in the room

X = the proportion of CO₂ found in the air of the room

N = the proportion of CO₂ in the outside air

A = the air supply in c.ft. per hour

VP is then the CO₂ produced by the occupants and X — N is the respiratory addition. The amount of CO₂ produced by one person averages 0.6 c.ft. per hour, and the average proportion of CO₂ in the air is 4 parts in 10,000.

$$\text{thus } A = \frac{0.6p}{X - 0.0004}$$

Each person will add 6 parts of CO₂ in 10,000 to 1000 c.ft. of air and the total CO₂ will be 10 parts in 10,000. To keep the CO₂ no higher than this a supply of 1000 c.ft. per hour of fresh air will be required for one and for fifty persons 50,000 c.ft. per hour.

Crowder, by estimating the percentage of CO₂ in sleeping railway cars occupied by people, found for wood cars with window sashes in the roof, the ventilation to be :

fully closed 18,500 c.ft. per hour

open roof sashes 28,300 c.ft. per hour

open roof and end doors 40,700 c.ft. per hour

for steel cars with exhaust roof ventilation :

fully closed 53,000 c.ft. per hour

Drop sashes in end door

open 65,900 c.ft. per hour

The steel sleeping cars have six to eight exhaust ventilators fitted in the roof, actuated by the motion of the train. The air enters by the crevices of doors and windows in the breathing zone. The effect of running the train was to lower the percentage of CO₂ from about 0.14 to 0.05, the higher figure pertain-

ing when the train stood in a siding. No draught is felt in these steel cars. The oppression felt by an Englishman in such cars is due to body heat stagnation, he being not used to the American standard of heating and not suitably clothed for it. In railway carriages the heating apparatus should be put so as to very gently warm the floor so as to give warm feet. The present arrangement of the pipes under the seat gives people hot heads and cold feet. If the feet were kept warm far less heat would be required, and much pleasanter and healthier conditions obtained.

The following comparative observations on ventilation were recorded by the CO₂ method by Crowder in U.S.A.

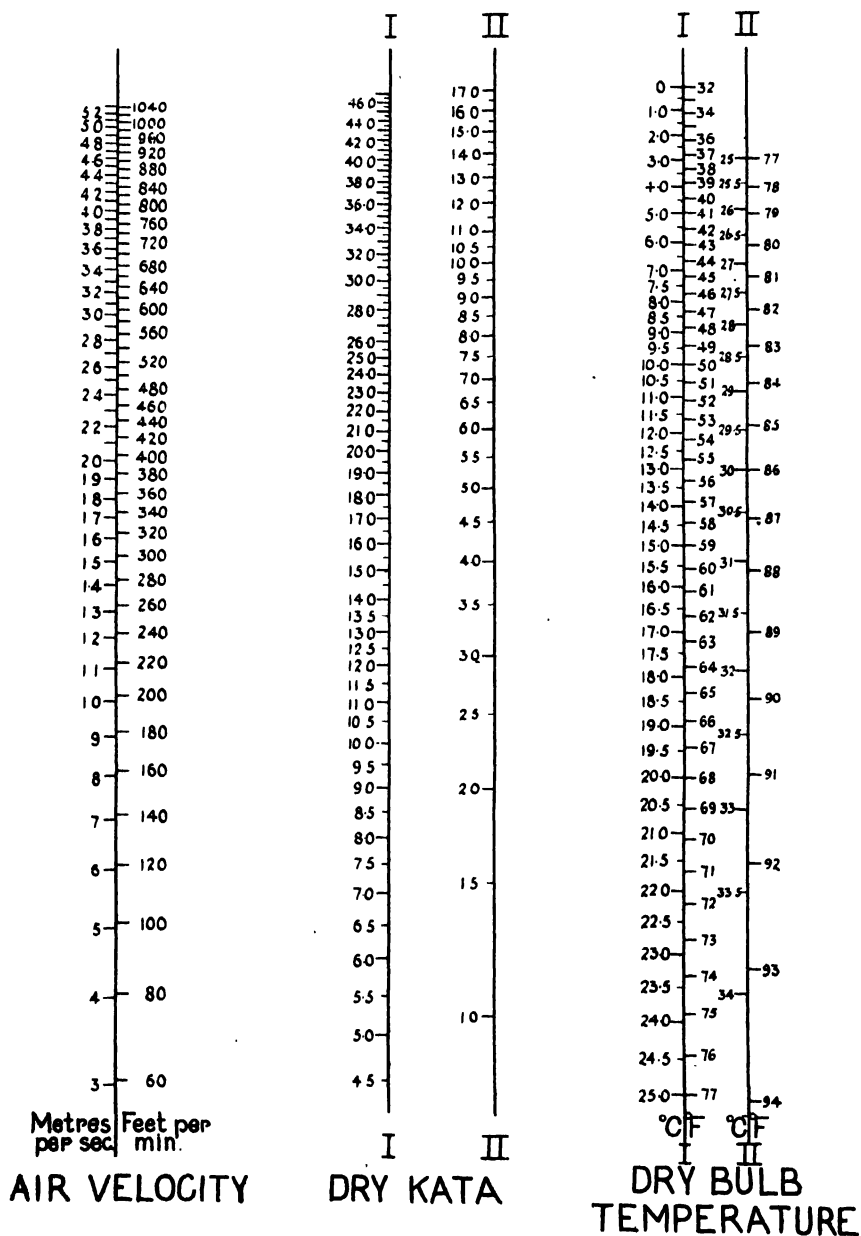
				CO ₂ per 10,000	Calculated air supply per person per hour in cu. ft.
Street cars	...	..	...	15-29	541
Elevated cars	...	...	...	14-26½	674
Suburban coaches	...	...	...	14-38	583
Stores	...	...	...	9-10	1250
Restaurants	...	...	...	16-26	406
Offices	...	...	...	14-19	670

Given other things equal a low and small room is far better ventilated naturally than a large and lofty one, because in the case of the small room the surfaces through which ventilation takes place are much greater in proportion to the volume of air contained within the room. Height and cubic content are then absurd standards to set up in building bye-laws. Taking the heat loss of a man at sedentary occupation by convection and radiation as 60 Cal. per hour, it can be calculated that six men in three hours will raise an unventilated space of 200 c. metres with no heat loss from 50°F to 82.5°F. Taking 50 gm. of water as the evaporative loss per man per hour, it can be calculated that the wet bulb in the same time might rise from 42°F to 64°F if the air to start with were 50 per cent. saturated. Supposing half the heat and water vapour is lost, 12 men would be required to effect this, with three quarters lost fifteen men, and so on in proportion. In a deep dugout with content of 900 c.ft., with exits closed by anti-gas curtains and 30 persons and 3 lighted candles inside it, the dry bulb rose in 1 hr. 40 minutes from 10.5 to 17.4°C. and the wet bulb from 9.8 to 13.4°C and the carbonic acid to 0.6 per cent. The dugout was thus kept in conditions not uncomfortable, by natural ventilation on a cold day, with an air volume of about 1 c. metre or less than 40 c. ft. per man. During hot weather with the temperature inside and out much the same in a shut up room crowded with people the natural ventilation will be small and the temperature will rise in the room so that there results the discomfort of a stagnant warm moist atmosphere; finally if the occupation is continued, heat stroke will result as in the Black Hole of Calcutta. In crowded conveyances, buses, trams, railway cars while moving, risk of heat stagnation only arises in very hot weather, and with the sun beating down on the roof.

DRY KATA NOMOGRAM

WHEN SCALE I IS USED FOR TEMPERATURE SCALE I MUST ALSO BE USED FOR KATA

SCALE II SCALE II



DIRECTIONS FOR USING THE DRY KATA NOMOGRAM.

The nomogram connects the three variables, dry kata reading, dry bulb temperature, and air velocity.

To read off any one of these, join the observed values of the other two by a straight edge, and read off the required value at the point where the straight edge cuts the third scale.

If Scale I has to be used for the temperature, Scale I must also be used for the kata, and if Scale II is used for temperature Scale II must also be used for the kata. The temperatures can be read in either Centigrade or Fahrenheit, and the velocity in either metres per second or feet per minute.

The nomogram has been drawn from the equation

$$H = (0.50803 \sqrt{v} + 0.10551) (36.5 - t)$$

Where H = Dry Kata reading.

v = air velocity in metres per second.

t = dry bulb temperature in $^{\circ}\text{C}$.

$$\text{or } H = (0.020116 \sqrt{V} + 0.05862) (97.7 - T)$$

Where V = air velocity in feet per minute.

and T = dry bulb temperature in $^{\circ}\text{F}$.

The observations on which these equations were based only extended over the following ranges :

$$\left\{ \begin{array}{l} \text{Air velocity } 0.31 \text{ m. per sec. to } 5.2 \text{ m. per sec.} \\ \text{Dry Bulb } 0^{\circ}\text{C to } 44.5^{\circ}\text{C.} \\ \text{Relative humidity } 28 \text{ to } 95 \text{ per cent.} \\ \text{Barometer } 735 \text{ mm. to } 760 \text{ mm.} \end{array} \right.$$

and extrapolations beyond these ranges should not be made. These equations can only be taken as approximate, not as exact, as the observations on which they are based are subject to experimental error which is greater in the case of the Wet Kata than in that of the Dry.

DIRECTIONS FOR USING THE WET KATA NOMOGRAM.

The nomogram connects the three variables, wet kata reading, wet bulb temperature (ventilated), and air velocity.

To read off any one of these join the observed values of the other two by a straight edge, and read off the required value at the point where the straight edge cuts the third scale.

If Scale I has to be used for the temperature, Scale I must also be used for the kata, and if Scale II is used for temperature Scale II must also be used for the kata. The temperatures can be read in either Centigrade or Fahrenheit, and the velocity in either metres per second or feet per minute.

The nomogram has been drawn from the equation :

$$H' = (1.115v^{0.4} + 0.268) (28.65 - 0.409t' - 0.00346t'^2 - 0.000224t'^3).$$

where H' is the Wet Kata reading.

v = Air velocity in metres per second.

t' = Wet bulb temperature in $^{\circ}\text{C}$.

$$\text{or } H' = (0.1347V^{0.4} + 0.268) (36.08 - 0.2766T' + 0.00261T'^2 - 0.000383T'^3).$$

where V is the air velocity in the feet per minute and T' the wet bulb temperature in $^{\circ}\text{F}$.

The observations on which these equations were based only extend over the following ranges.

$$\left\{ \begin{array}{l} \text{Air velocity } 0.31 \text{ m. per second to } 5.2 \text{ m. per second.} \\ \text{Dry Bulb } 0^{\circ}\text{C to } 44.5^{\circ}\text{C} \\ \text{Wet Bulb } 0^{\circ}\text{C to } 33.5^{\circ}\text{C} \\ \text{Relative Humidity } 28 \text{ to } 95 \text{ per cent.} \\ \text{Barometer } 735 \text{ mm to } 760 \text{ mm.} \end{array} \right.$$

and extrapolations beyond these ranges should not be made. These equations can only be taken as approximate, not as exact, as the observations on which they are based are subject to experimental error which is greater in the case of the Wet Kata than in that of the Dry.

I have investigated, by means of the kata-thermometer, the ventilation in public conveyances. The kata-thermometer is the most delicate of anemometers and the nomographs given herewith have been worked out in wind tunnels with great care, and afford a ready means of determining ventilation by this instrument. I am indebted to the great assistance of Mr. T. C. Angus and Miss Newbold in preparing the new nomographs which are only just completed.

The following are readings obtained for me in conveyances by Miss M. Brad :—

Steam Trains		Cooling power dry kata	Tempera- ture of	Velocity of air feet per minute.
August	Windows closed	5	70½	27½
	„ open, back to engine	8	67	96½
	„ open, facing engine.	11½	64½	214½
October	Windows closed	8	54	21
	„ open, back to engine	10½	50	49
	„ open, facing engine	18½	49½	289
October	Open Top of bus between Liverpool Street and Shepherds Bush	14½	57	232
	Open top of bus between Golders Green and St. Albans bright, sunny, cold wind.	30½	51	1043
	Inside bus between S. Norwood and Charing Cross	9	61	71
August	Trams L.C.C.	4	71½	12½
	Ditto	6	67	35½
August	North London Railway (Electric).	4	75	16
October	Ditto	7	63½	31
August	Tube Railways	5-8	66-75	28-118
October	Tube Railways on the platforms.	7-10	63-72	168-425

In the Tropics a white reflecting surface and double roof with ventilated air space is required to keep off the heat of the sun, and electric fans to increase the ventilation when the train stops. So too, in this country, the whitening of railway car roofs in the summer and the provision of electric fans in dining cars is of great advantage.

In ships a sufficient current of air is required in all cabins to prevent body heat stagnation and produce comfort. The direction of the current should be variable and people should be warned not to fall asleep with a current of air playing on some naked part of the trunk for fear of overcooling it and causing rheumatic pain and stiffness. In the engine room of an Atlantic liner there were provided three very large open fans at the bottom of wide air trunks which distributed fresh unheated air in fine streams. The engineers called these joy wheels. The temperature was 75-80°F. dry bulb and 65-71°F wet bulb. The 'kata' readings were 4-7 dry and 16-25 wet. These readings

show how fans take away all the discomfort of hot places. In second class cabins (October the outside temperature 61°F) the temperature was 76°F . dry and 68 wet, the 'kata' $3\frac{1}{2}$ -4 dry and $12\frac{1}{2}$ -15 wet. With the ventilator full on, the 'kata' figures rose to 5 dry and 20 wet. In third class cabins, the kata readings were 4 dry and 12 wet. Such readings are too low. In other parts of the ship the readings were up to standard. These readings were obtained for me by Mr. T. C. Angus.

The conclusion reached from the research is that public conveyances are in some cases ventilated so that the 'kata' readings are obviously too low, e.g., 4, a figure at which visible sweating takes place. In other cases standard 'kata' figures are reached, but the ventilation might with advantage be larger in order to reduce 'droplet' infection. With open windows in railway compartments, in open cars and tops of buses the good effect of exposure to fresh air can be had, and people would be well advised to clothe themselves adequately and bear with such as far as possible. Heating the floor gently and so warming the feet would enable people to enjoy such ventilation. The roof ventilators of railway cars can be so arranged as to secure a fair rate of ventilation when the train is running, but extract fans are required to maintain ventilation when the cars are stationary. There is a general tendency to keep railway cars too shut up and too warm.

A matter of importance is the contamination of the air in tunnels and garages with carbon monoxide. This gas has a far greater affinity for haemoglobin than oxygen (some 250 times greater) and when breathed displaces oxygen from the blood and so brings about death through oxygen want. The partly poisoned person must be made to breathe a mixture of 5 per cent. carbonic acid with oxygen. This stimulates breathing and displaces the carbon monoxide from the blood. Even after resuscitation from severe poisoning there may follow degeneration of the heart muscle etc., due to the prolonged oxygen want, and no complete recovery may result. It cannot be too widely known that the exhaust gas of motor cars is heavily charged with carbon monoxide, e.g., 8 per cent., and people must be generally warned of the great danger of running cars in shut up places. Many lives have been lost through running a car in a shut up garage, and much ill health is produced among employees in ill-ventilated garages through breathing carbon monoxide. Any percentage higher than 0.01 should be considered unsafe. In tunnels like the Blackwall, whenever traffic is held up all cars should cease to run. In the New York Tunnels special provisions have to be made to secure a non-dangerous percentage of carbon monoxide. Even in the streets, in the jams of stationary cars, the percentage may rise to 0.01-0.02 and the blood of the traffic controllers show 20 per cent. of the haemoglobin to be combined with this gas, and it has been suggested that all exhausts should be made to open at the top of the body of the car so as to carry the fumes upwards.

Ozone has been used for improving the conditions of the air in tube railways.

Ozone is a gas which is irritative to the respiratory membrane and can only be safely used in very low concentrations, such as can just be sensed by smell, e.g., 1 in 10 million parts of air. Captain Douglas and I have just got evidence that certain sprays of disinfectant, which are used to freshen the air in crowded places, may help to produce sterilisation of the air by killing microbes. These substances also act by altering the monotony of sensation. They possibly excite a greater secretion of mucus and lymph in the breathing tubes, and so secure a better cleansing of the respiratory membrane.

Great loss of working power and discomfort which tends to ill health is caused by the delay of traffic due to fogs. To get rid of smoke pollution is the great reform required to-day. The greater temperature and dryness produced in cities is lessening the natural mist of the country very greatly, and a vast improvement of health and good spirits would result from the use of smokeless fuel, gas coke, etc., in all domestic fires and in factories, together with a great economic gain. The smoke pollution is most destructive to clothing, decorations, building materials, green food, flowers and trees, makes everything dismal and dirty, and the atmosphere dark and cold, cutting out the health-giving rays of the sun. The prolonged delays standing at stations waiting for trains on foggy days, the tedious journey lasting one or two hours with carriages packed with people owing to reduction of service, is a curse which people patiently endure. Inefficient methods of signalling continue to be used to save the shareholders money, while the community at large suffer year after year. The bottle neck into Liverpool Street Station continues to obstruct traffic and waste the time of hundreds of thousands of people in the course of a year. A greater example of inept government could not be found.

One of the causes of crowding in trains is the division into first and third class carriages. In crush hours the public break down this division, jump in anywhere, and the railway officials connive at the invasion of the rights of the first class passengers. In the tubes the division into classes is abolished and nobody is a bit the worse for it. The District and Metropolitan Railways ought to follow this example. In the case of long railway journeys there is advantage in first class carriages for business men who have to travel often, but given saloon carriages fitted with tables very little loss of comfort would result from a general abolition of first class, and the public as a whole would gain from less crowding and better service. The Government would gain a little by saving the first class fares of its higher officials, but what is such a saving compared with the cost of one war vessel?

DISCUSSION.

THE CHAIRMAN said he was sure he was voicing the feelings of all present when he said that they had listened to a most illuminating address. Many new ideas had been brought before them with a most lucid power of expression. The importance of light and air was surely now admitted by everyone—at any rate by all

those people who thought. It had not yet quite found its expression in the habits of the people to the extent to be desired and hoped. Where the young were concerned—where they dominated the position (which they increasingly did), there were very few difficulties in the way. For instance, in children's institutions and open air schools, where the young were the chief concern, it was relatively easy, if only they had enlightened leaders, to bring them up on open air principles, and with every word which Professor Hill had said upon that matter every medical man would agree. If one were building a children's hospital at the present time one would not be so foolish as to spend a lot of money on concrete, brick and marble. What one would do, if one went a little way out of London, would be to build a hospital of the lightest possible material. Some of the most successful of such buildings were erected on the cattle byre plan, completely open, made of wood with a concrete floor, which floor continued for some yards outside the byre. In the daytime the beds were pulled out into the open, and at night they were just pushed back again under the shelter. The children in such hospitals got well in a way which was positively astonishing. If any one of his audience desired to see the good effect of air on a child he would advise him to go down some day to Hayling Island. The last time he himself had been there had been on a November day, and he had found the children running about naked on the beach with just a loin cloth on, looking the picture of health, warmth and gladness, with perfectly beautiful skins. If anyone wanted a beautiful skin there was nothing like open air to bring about that effect. As those children passed into adult life they would perpetuate those habits of fresh air and would not contract those respiratory diseases which were the causes of so many fatal cases in the old. The effect of that on public health would be progressive. Robust frames would be seen everywhere and a race would be produced such as was being produced now. The boys and girls of to-day were an increasing joy to look upon—a state of things which was largely due to modern mothers in bringing their children up in the fresh air. Coming to the public conveyances of to-day, one was met by the initial difficulty that one was dealing with a "mixed bag," and one must not allow the children entirely to dominate the position. Taking the middle-aged people of to-day, one must "temper the wind to the shorn lamb." There were many people who, directly they got tired, got cold; they were usually people of low blood pressure. They contracted cold extremities, and when they were in that condition they were very apt, if exposed to any kind of draught or chill, to break down in one or other of their functions. It had to be borne in mind that there was that class of person who found the modern type rather trying to live with. The question of fatigue in relation to cold was a very important one. There were many who when fatigued could not stand fresh air except in moderation, and unless very carefully clothed. For such people to take exercise was damaging to them; they had to confine their exercises to that time of the week when they were not using their heads in offices. Therefore, although cold was not the direct cause of bronchial catarrh or of pneumonia, it did have the effect on certain people of rather weakly constitutions or who were very susceptible to cold, that it lowered their resisting power to such an extent that if they were chilled on the way home they were very prone to get pneumonia or bronchitis. That did not in the least belittle his agreement with Professor Hill that fresh air was needed, and "catching cold" in the ordinary sense was a damaging and misleading expression; nevertheless in practice he thought the methods would have to be modified in relation to the "mixed bag." Professor Hill had said that overcoats should be dispensed with by people who went out of doors. No doubt that was admirable advice for the young, but not

for people of the class about whom he had just been talking. For such people to go on to the top of an omnibus in order to get ventilation would raise the death rate and not diminish it.

On the subject of clothing, men did want to imitate their womenfolk, who had attenuated their clothing to an extent which had not only increased the gladness of life by adding to its beauty, but incidentally was rearing a number of vigorous young women who were improved in physique out of all proportion to many of their male contemporaries. It took a modern girl less time to undress and dress than a man of the same age. Just think what the position would have been in the later Victorian times! It would have been as 4 to 1; now it was about as 5 to 4 the other way. That was largely due to the fact that women's clothing at the present time was very much more sensible than it used to be; and personally he thought that male clothing—especially of the sort he was wearing at the moment—needed seriously to be modified.

He could not allow one sentence of the paper to pass without comment. Professor Hill had said that from a physiological point of view alcohol narcotised and did nothing else. No doubt that sentence would keep Lady Astor and the Bishop of London warm and vigorous for a considerable time, and no doubt they would make full use of it; but neither a person nor a thing should be judged by their effects in excess. It was true that alcohol narcotised in excess, but it did not narcotise when taken at the proper times and in good seasons. Anything which gladdened the heart of man added to his health, and alcohol had its part. A speech in moderation might gladden the heart, but certainly narcotised in excess; the same applied to a sermon or to conversation in the home.

MR. FRANK PICK (Managing Director, Underground Railways and London General Omnibus Company) said the Underground Companies' business was rather to carry people than to practise upon them experiments in order to see exactly how their physique responded to various conditions of temperature and ventilation. In the past the public had not thanked his Company for what experiments they had made upon them! His Company had tried all kinds of systems of ventilation for its vehicles. They had installed roof ventilation, side ventilation and end ventilation; but they had found that so long as they had left the ventilators in such a position that the passengers could choose whether they were open or shut there had been endless disputes as to the exact state in which those ventilators should be, and the staff had appealed to headquarters from time to time to take steps to remove that temptation from the public. After much consideration the Company had now provided in all their vehicles a ventilation system which was beyond the control of the passengers and of the conductors.

Professor Hill had suggested that the London General Omnibus Company had covered in the tops of their omnibuses in order to make a larger profit. That was looking at the matter from a somewhat narrow point of view. At certain times of the day large masses of people had to be carried—many more than could be provided for under the very best of circumstances. On wet days it had been found in the past that at least half the travelling accommodation provided had been thought to be unhygienic, and his Company had been compelled, in order to get the people away and in order to avoid the congestion which took place upon the tube railways, to cover in the tops of their omnibuses. In compensation therefore they had provided sliding windows along each side, not only of the covering, but also of the lower deck, by which an admirable draught was created, and he was sure that Professor Hill's kata-thermometer under those favourable circumstances

would register a very high rate of evaporation. He had listened to the lecture with the greatest possible amount of interest. With the aid of Professor Hill's exposition his Company might still further improve the compulsory ventilation which they gave to their passengers.

THE REV. CHANCELLOR PONSONBY, said he understood that any single passenger in an omnibus had the right to close every window except the centre one of the three in front; and that if any one person in the omnibus desired to have that particular window open it had to be opened by the conductor. He would like Mr. Frank Pick to say whether that was the fact or not.

MR. FRANK PICK said that when his Company had cut the louvres in the upper front of the omnibus it was found that the current of air went only along the top of the omnibus and out through the door; they had had no effect whatever on the lower strata of air in the vehicle. In order to get over that difficulty in the summer time they had introduced a ventilator which tilted upwards in the lower part of the glass in front of the omnibus which threw the current of air along the floor. Instructions had been given to the conductors that that was to be kept open in hot weather. He could not say offhand exactly whether the rules which had been made for the guidance of the Company's conductors were rigidly observed, and therefore he was afraid he could not answer the previous speaker's question.

MR. G. HALLY, speaking as a representative of one of the railways, said that on the question of ventilation he could state that certain passengers had written complaining of the lack of ventilation and that others had written to the opposite effect. Sometimes complaints have been received about the same type of rolling stock. One man considered that there was too much ventilation, and another man that there was too little.

He would like to point out with regard to tunnels, that there was a considerable amount of dust caused by the rubbing away of the brake blocks, and if the windows were left open too long, some of the cast iron dust found its way into the carriage and passengers complained about it. It might be harmful or it might not; he could not say, but his Company were taking whatever steps they could to satisfy everybody, although it was a difficult matter, for some people wanted one thing and some wanted another.

DR. GRAHAM FORBES said everyone owed the lecturer a very great debt of gratitude for his extremely illuminating, convincing and comprehensive address on the very important subject of fresh air, ventilation and sunlight. Some years ago, in 1920, he (Dr. Forbes) had had practical experience on the question of air pollution in our tube railways, and although he could not pretend that he had touched the subject since that time, he thought it might be interesting for the audience to hear some of the details of that work. Careful controls had been carried out in order to compare the air in the actual carriages and on the platforms with the open air. Taking into account, from the bacteriological standpoint, the organisms which developed at room temperature and body temperature (though the latter group was perhaps of more particular interest to them), it had been found that those developing at room temperature showed that the air of the tube railways compared not unfavourably with the open air. For instance, the ratios which had been obtained showed that where the open air figure was placed at 10, the average of those organisms growing at room temperature was 14—which might be taken as showing not a grave degree of pollution. But the individual figures going to form

that average of 14, when one came to consider the different railways which had been investigated, varied rather considerably. Of those railways the Central London had come out with the best results at just under 12; the Bakerloo 12.6; the Piccadilly and Brompton and Hampstead and Highgate at 13; the Metropolitan 14.6, and the City and South London Railway (which he was thankful to say no longer existed under the conditions which then prevailed) 15.7. When, however, one came to deal with the organisms growing at body temperature a considerably greater difference was to be found and the ratio of open air to the tube railway bacteria became exactly as 1 to 2 instead of as 10 to 14; that was to say, in the tube railways there were twice as many growing at body temperature as in the open air. In that body temperature group, again, considerable differences had been obtained between the different railways. The Central London had again shown the lowest and the Metropolitan the highest amount of pollution. As regards the highest degree of pollution obtained, it had been found that in the Central London Railway the pollution, compared with the open air, had amounted to $2\frac{1}{2}$ times as much; the Bakerloo 4 times; the City and South London 3 times; the Piccadilly and Brompton 3 times; the Hampstead and Highgate $4\frac{1}{2}$ times, and the Metropolitan 5 times as much as in the open air. It was interesting to note that in investigating the air on the platforms and in the passages the averages of the bacterial content were generally higher than in the train carriages, and in one instance an unusually high result had been obtained. At the foot of the Oxford Circus moving staircase a degree of pollution had been found which was ten times that of the outside air, amounting to about 22 per litre. The question of variation in pollution compared with the amount of increase in passengers travelling had also been studied, as had also the matter of overcrowding, and it had been found, as might be expected, that with the increase in passenger rate up had gone the bacterial content of the air. That increase had not been constant; it rose up to a certain point as the carriages got more and more full, but the rate of increase was not in direct numerical proportion to the increasing passenger density, owing no doubt to the obstruction to circulation of air currents by the crowds blocking the compartment. Then there arose the important question of atmospheric moisture. It had been found that with increasing humidity so had risen the bacterial content. With rising passenger rates there had occurred a rise in atmospheric humidity favourable to the survival and conveyance of organisms which were so dependent on moisture, and with that rise in humidity was obtained an increase in the number of organisms present. The question of humidity was a very important one in so far as the spread of infection was concerned. Where there was free ventilation there was far less risk of bacteria surviving. The question of the risk of spread of infection by droplets spread in coughing, sneezing and loud talking, to which passengers in a crowded compartment were exposed, was also a very important one. There was every facility for the spread of infection through droplets at close range, and of the transference in massive doses.

As regards the differentiation of organisms present in tube railway air, it was significant that of those investigated in detail 20 per cent. were found to belong to the mouth and nasal passages and the skin of human beings. It had not been possible to prove their pathogenicity, but their source and comparatively high percentage indicated clearly the great probability of disease germs being easily conveyed from person to person in a crowded compartment, in the case of, *e.g.*, influenza, diphtheria, pneumonia and tubercle.

The unpublished chemical investigations of tube air, undertaken at the same time as the bacteriological in 1920, combined to show a close correlation between

passenger density, weight of water vapour, percentage humidity and the amount of carbon dioxide pollution on the six railways, and a correspondence with the bacterial content, most marked in the case of the Inner Circle of the Metropolitan Railway and higher on that railway and the old City and South London Railway than on the four other tube railways, dependent on overcrowding, and, on the Metropolitan Railway, partly due to defective carriage ventilation from the use of the old type of carriage with windows difficult to open and therefore seldom opened.

Some recent work had been done on the New York subway railways last March by Dr. David Miller, who had carried out a number of investigations. That observer had found very definitely that over a certain railway space, covering about eight stopping stations, at the commencement of the journey the bacterial content had been at a fairly low figure, but by the time the end of the journey had been reached the bacterial content had been increased ten-fold. Tests had been carried out both in rush and non-rush times, and had shown a steady rise as the journey progressed. In the case of the non-rush hours it had amounted to a ten-fold, but during the rush hours it had reached a hundred-fold increase by the end of the journey, so that in crowded conditions the pollution was ten times what it was in the non-rush period.

It was satisfactory to read that the old type of vehicle and rolling stock would soon be dispensed with, and that new and up-to-date ventilated stock would be provided. The present six-wheeled and possibly future eight-wheeled omnibuses provided, and would provide, considerably more accommodation than the older type of four-wheeled vehicle. Therefore, without adding to the number of vehicles on the streets, better means would be afforded in dealing with the present great congestion, and so help to solve the great problem of passenger transport in London.

A vote of thanks to Professor Hill, having been passed unanimously, the meeting terminated.

MR. F. W. ALEXANDER, M.R.C.S., L.R.C.P., D.P.H. (late Medical Officer of Health for the Metropolitan Borough of Poplar) writes:—For years I have complained about the overcrowding of railway carriages. When Medical Officer of Health for Poplar I made a report and have written to the Medical Press upon the subject. As usual I was dubbed a faddist. I am pleased to see your Council has moved. How can one expect an Air nation when the workers are herded together, standing in compartments travelling to their labours and suffering the same condition after a day's work, possibly in an underground office or in one which is none too well ventilated. Is it to be wondered that workers, chiefly girl typists and clerks, suffer from claustrophobia and nervous breakdowns? Consider the disgraceful condition during rush hours of the District Railway carriages east of Aldgate and the suburban South-Western trains. In the latter the third classes are packed, and when one travels in a first-class, which is empty, with a third-class ticket, one is asked to pay or threatened with legal proceedings. The South-Western Company have pleaded the war and promised to have matters mended, but nothing material has happened. Do away with first-class compartments on local and suburban lines, also construct more tubes. Such a terrible state of affairs as overcrowding in railway carriages should cease in these times. The nation will be ruined, the fœtid atmosphere of overcrowded carriages tending to cause consumption in the tired workers and the herding together affecting their nervous systems.

CORRESPONDENCE.

ROAD TRAFFIC PROBLEMS.

I have read in the *Journal* of November 25th the discussion which followed Colonel O'Gorman's paper on "Road Traffic Problems of the Pedestrian." I now see that I made an important omission which I beg that you will give me space to remedy.

I omitted to point out that one of the dangers to the walker, when attempting to cross a heavily trafficked street after nightfall, is greatly increased by motorists not showing sufficient care in the use of their lights, for although they have been warned never to turn on their powerful headlights in towns, many of them still use these lights, thus producing a glare which not only blinds motorists or walkers meeting them, but so dazzles any walker wishing to cross the road that he is unable to estimate the distance from him of any of the vehicles coming towards him on the near side of the road. In addition, many of the side lights on the vehicles are far too powerful for town traffic, as they produce dazzling effects almost as confusing as the full power headlights. There are very few cases in town traffic where motors need to use lights more powerful than those used on the taxicabs or on the omnibuses.

Another point which I omitted is that all motor drivers should be warned never to overtake other vehicles when they are approaching refuges or similar spots which walkers are advised to use as crossing places.

We are all in hearty agreement with Colonel O'Gorman that in towns the rule of the pavement should be made absolute to keep to the left.

R. E. CROMPTON.

OBITUARY.

LORD KENYON, K.C.V.O.—We regret to announce the death of Lord Kenyon, at the age of 63, on November 30th, at Gredington, Flintshire. Born in London on July 5th, 1864, he was the only son of the Hon. Lloyd Kenyon, and at the age of five succeeded his grandfather as the fourth Lord Kenyon of Gredington. He was educated at Eton and Christ Church, Oxford, and, later, took a keen interest in the University of Wales, of which he was Pro-Chancellor, and was also an authority on agricultural and dairy matters, being appointed Chairman of the Advisory Committee on Milk, and of the Agricultural Wages Board, in 1924. He was also President of the North Wales University College and of the National Museum of Wales. In 1924 he visited the United States on the occasion of the centenary celebrations of the Kenyon Theological College, Ohio, to which he was invited because his ancestor, the second Lord Kenyon, had helped to raise £10,000 for the foundation of the College.

Lord Kenyon took a prominent part in county matters, being Lord-Lieutenant of Denbighshire and formerly Colonel commanding the Shropshire Imperial Yeomanry. During the war he was in command of the 2nd/1st Welsh Horse from 1914 to 1916.

Lord Kenyon was a Lord-in-Waiting to three sovereigns—to Queen Victoria, King Edward VII and King George V—and was created K.C.V.O. in 1907. He had been a member of the Royal Society of Arts for nearly forty years.

MEETINGS OF OTHER SOCIETIES
DURING THE ENSUING WEEK.

MONDAY, DECEMBER 12.—Automobile Engineers, Institution of, at the Queen's Hotel, Birmingham. 7 p.m. Dr. A. F. Burstall, "Experiments on various Gaseous Fuels in a High-Speed Internal Combustion Engine." Brewing, Institute of, at the Charing Cross Station Hotel, Strand, W.C. 7.45 p.m. Mr. W. H. Harman and Dr. J. H. Oliver, "Finings." British Academy, at Burlington House, W. 5.15 p.m. Dr. M. R. James, "The Apocalypse in Art." (Lecture I.)

Electrical Engineers, Institution of, at the University, Liverpool. 7 p.m. Professor Dr. E. W. Marchant, "High Frequency Currents." (Kelvin Lecture). At Armstrong College, Newcastle-on-Tyne. 7 p.m. Mr. D. B. Hoesason, "Squirrel-Cage Induction Motors."

Geographical Society, at Lowther Lodge, Kensington Gore, S.W. 5 p.m. Dr. Venning Meiners, "Gravity Surveys by Submarine via Panama to Java." Metals, Institute of, at 39, Elmbank Crescent, Glasgow. 7.30 p.m. Dr. Robert Hay, "Age Hardening of Alloys." Philologie, Sciences et Beaux-Arts, Société Internationale

- de, 8, Taviton Street, W.C. 3.30 p.m. Mr. G. C. Meiklejohn, "Early Man in Scotland."
- Swiney Lecture, at the Royal College of Science, South Kensington, S.W. 5.30 p.m. Dr. Robert Campbell, "The Geological History of Scotland." (Lecture I—Introductory.)
- Transport, Institute of, at the Queen's Hotel, Birmingham. 6 p.m. Mr. W. Donaldson Wright, "Organisation of the Transport of Goods by Road."
- University of London, at King's College, Strand, W.C. 5.30 p.m. Major-Gen Sir Frederick Maurice, "Principles of Strategy." (Lecture II.)
- At the Royal College of Surgeons, Lincoln's Inn Fields, W.C. 4 p.m. Mr. F. W. Twort, "The Technique of Bacteriological Research." (Lecture IV.)
- At University College, Gower Street, W.C. 5.15 p.m. Mr. Hilary Jenkinson, "Seals, Mediaeval and Modern."
- TUESDAY, DECEMBER 13.** Asiatic Society, 74, Grosvenor Street, W. 4.30 p.m. Mr. Muhammad Nazim, "Somnath and its Conquest by Sultan Mahmud of Ghazna."
- Automobile Engineers, Institution of, at the Broadgate Café, Coventry. 7.30 p.m. Mr. W. A. Whatmough, "Control in Carburation."
- Civil Engineers, Institution of, Great George Street, S.W. 6 p.m. Messrs. K. H. Turner and K. E. Walsh, "The Reconstruction of Two Railway Swing Bridges between Ipswich and Great Yarmouth."
- Electrical Engineers, Institution of, at the Hotel Metropole, Leeds. 7.15 p.m. Mr. W. McClelland, "The Applications of Electricity in Warships." At the Engineers' Club, Manchester. 7 p.m.
- At the Royal Technical College, Glasgow. 7.30 p.m. Mr. F. H. Clough, "The Stability of large Power Stations."
- Illuminating Engineering Society, at 15, Savoy Street, W.C. 6 p.m. Mr. J. L. H. Cooper, "An Investigation of Electric Lighting in the Engineering Industry."
- Mechanical Engineers, Institution of, at Swansea, Messrs. J. Adamson and F. Jones, "Reduction of Steel Works Costs by the Use of Waste-Heat Boilers."
- Opticians, British Practical, 8, Taviton Street, W.C. 8.15 p.m. Mr. Eric H. Mayer, "Tortoiseshell."
- Petroleum Technologists, Institution of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 5 p.m. Mr. H. R. Kicards, "Detonation in Motor Fuels."
- Photographic Society, 35, Russell Square, W.C. 7 p.m. Meeting arranged by the Scientific and Technical Group.
- Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Sir William Bragg, "A Year's Work in X-Ray Crystal Analysis." (Lecture IV.)
- Transport, Institute of, at Leeds. Mr. D. Harvey J. Hartley, "Railway Goods Rates: Revision and the 'Appointed Day'."
- University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Sir Bernard Pares, "Russian History to 1861." (Lecture X.)
- WEDNESDAY, DECEMBER 14.** Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Mr. Ernest Law, "Hampton Court Palace."
- Automobile Engineers, Institution of, at the Engineers' Club, Manchester. 7 p.m. Mr. G. J. Rackham, "The Modern Motor Bus."
- British Academy, at Burlington House, W. 5.15 p.m. Dr. M. R. James, "The Apocalypse in Art." (Lecture II.)
- British Empire Producers' Organisation, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 4.30 p.m. Mr. Ben H. Morgan, "The Effect of Preference on Empire Development."
- Civil Engineers, Institution of, Great George Street, S.W. 6.30 p.m. Mr. E. C. Cookson, "The Reconstruction of Paddington Goods Station, G.W.R."
- Geological Society, Burlington House, W. 5.30 p.m. Dr. E. Greenly and Dr. Stanley Smith, "The Lower Carboniferous Rocks of the Menai Region of Carnarvonshire: their Petrology, Succession and Physiography."
- Meteorological Society, 49, Cromwell Road, S.W. 5 p.m. (1) Sir Napier Shaw, Mr. R. G. K. Iempfert and Miss E. E. Austin, "International Commission for the Upper Air: Report on the International Days of 1923. (2) Sir Napier Shaw, "Geopotential and height in a Sounding with a Registering Balloon." (3) Messrs. L. F. Richardson and R. E. Munday, "The Single-layer Problem in the Atmosphere and Height-integral of Pressure." (4) Messrs. L. F. Richardson, D. Proctor and R. C. Smith, "The Variance of Upper Wind and the Accumulation of Mass."
- North-East Coast Institution of Engineers and Shipbuilders, Bolbec Hall, Newcastle-upon-Tyne. 7.15 p.m. Mr. H. Caird, "Ship Ventilation."
- Public Health, Royal Institute, 37, Russell Square, W.C. 4 p.m. Professor Dr. E. W. Hope, "The Changed Conditions of Quarantine."
- Swiney Lecture, at the Royal College of Science, South Kensington, S.W. 5.30 p.m. Dr. Robert Campbell, "The Geological History of Scotland." (Lecture II—"The Geology of the North-West Highlands.")
- Transport, Institute of, at the Midland Hotel, Manchester. 6 p.m. Mr. R. Bell, "Lessons of Railway Statistics."
- University of London, at King's College, Strand, W.C. 5.30 p.m. Mr. Robert Peers, "Adult Education." 5.30 p.m. Baron A. F. Meyendorff, "The Crisis of Communism." (Lecture III.)
- At the Royal College of Surgeons, Lincoln's Inn Fields, W.C. 4 p.m. Mr. F. W. Twort, "The Technique of Bacteriological Research." (Lecture V.)
- THURSDAY, DECEMBER 15.** Aeronautical Society, Royal, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 6.30 p.m.
- Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m. Mr. D. B. Hoesason, "Squirrel-Cage Induction Motors."
- Linnean Society, Burlington House, W. 5 p.m.
- Mechanical Engineers, Institution of, at Birmingham. Sir William H. Bragg, "Application of X-Rays to the Study of the Crystalline Structure of Materials." (Thomas Hawksley Lecture.)
- Metals, Institute of, at the Engineers' Club, Birmingham. 7 p.m. Dr. L. Aitchison, "Duralumin."
- Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Mr. J. Kewley, "Petroleum Gases and their Derivatives."
- University of London, at University College, Gower Street, W.C. 5.15 p.m. Prof. de Montmorency, "Customary Law in the British Empire." (Lecture VH.)
- Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Professor A. M. Hind, "Wenceslaus Hollar: A Bohemian Etcher in London in the XVIIIth Century."
- FRIDAY, DECEMBER 16.** British Academy, at Burlington House, W. 5.15 p.m. Dr. M. R. James, "The Apocalypse in Art." (Lecture III.)
- British Electrical Development Association, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 7.30 p.m.
- Chemical Industry, Society of, at Liverpool. Mr. C. S. Garland, "Oil Pollution of Seas and Harbours—and a Remedy."
- London Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 5 p.m. Sir Frank Baines, "King Henry VIII's Hall at Hampton Court."
- Mechanical Engineers, Institution of, Storey's Gate, S.W. 6 p.m. Mr. Lawford H. Fry, "Some Experimental Results from a Three-Cylinder Compound Locomotive."
- Medical Officers of Health, Society of, 1, Upper Montague Street, W.C. 5 p.m. Drs. R. Veitch Clark, H. B. Brackenbury, Leonard West and A. H. G. Burton, "Health Aspects of the Poor Law Reform Proposals."
- Philologie, Sciences et Beaux Arts, Société Internationale de, 8, Taviton Street, W.C. 8.15 p.m. Mr. David Catt, "Canada."
- Swiney Lecture, at the Royal College of Science, South Kensington, S.W. 5.30 p.m. Dr. Robert Campbell, "The Geological History of Scotland." (Lecture III—"The Geology of the North-West Highlands" (continued.)
- University of London, at King's College, Strand, W.C. 5.30 p.m. Prof. J. W. H. Atkins, "Shakespeare in the Light of Ancient Literary Theory."
- SATURDAY, DECEMBER 17.** Royal Institution, 21, Albemarle Street, W. 3 p.m. Mr. F. J. M. Stratton, "Recent Development in Astrophysics." (Lecture II.)

JOURNAL OF THE ROYAL SOCIETY OF ARTS

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FRIDAY, DECEMBER 16th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

DR. MANN JUVENILE LECTURES.

Under the Dr. Mann Trust, PROFESSOR ARTHUR SMITHELLS, C.M.G., D.Sc., F.R.S., Director, Salter's Institute of Industrial Chemistry, will give two lectures for children on "Flame," at 3 p.m. on Wednesday, January 4th and 11th. The lectures will be fully illustrated by experiments.

Special tickets are required for these lectures. A sufficient number to fill the room will be issued to Fellows in the order in which applications are received, and the issue will then be discontinued. Subject to these conditions, each Fellow is entitled to one ticket admitting two children and one adult. Fellows who desire tickets are requested to apply to the Secretary at once.

The syllabus of the lectures was published in the *Journal* dated December 2nd.

SIXTH ORDINARY MEETING.

WEDNESDAY, DECEMBER 7th, 1927. CAPTAIN SIR ARTHUR WELLESLEY CLARKE, K.B.E. (Elder Brother of Trinity House), in the Chair.

A paper entitled "The Damage to Cargo due to 'Ship's Sweat'" was read by MR. S. J. DULY, M.A., Head of the Department of Commercial Products, City of London College. The paper and discussion will be published in the *Journal* dated January 6th.

BINDING COVERS FOR JOURNALS.

For the convenience of Fellows and others wishing to bind their annual volumes of the *Journal*, cloth covers can be supplied, post free, for 2s. each, on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.**FOURTH ORDINARY MEETING.****WEDNESDAY, NOVEMBER 23RD, 1927.****A. F. SUTER, ESQ., in the Chair.**

THE CHAIRMAN, in introducing the lecturer, said that Mr. Hedley Barry was peculiarly well fitted to deal with the subject of the lecture which he was going to deliver that evening. Mr. Hedley Barry had had very many opportunities of treating the resins in question both practically in quantities and technologically. He was certain the audience would not only receive plenty of enjoyment from the lecture, but, above all, instruction. Mr. Hedley Barry was not only a good technologist, but he had a touch of the Empire builder about him.

The following paper was then read :—

MALAYAN VARNISH RESINS.**By T. HEDLEY BARRY.**

When this Paper was first considered, I thought I might be able to give you an account of the various resins to be found within the confines of the British Empire, and the title suggested was "Empire Resins." I came to the conclusion, however, that this subject was far too large a one to be dealt with satisfactorily in the course of a single evening, and therefore decided to confine my remarks to that group of resins with which I have been most intimately concerned during the past three years, and which I feel are not only particularly interesting, but also particularly deserving of your attention.

Fully expanded my title would perhaps best be "Malayan Varnish Resins, with special reference to the work of the Forestry Department of the Federated Malay States and Straits Settlement in the development of the Damar Industry in the Malay Peninsula." The officials of the Forestry Department have indeed undertaken a task which all those who have to deal with resins will agree is of the utmost importance. They are endeavouring to supply us with definite standard grades of the resins found in their forests, the botanical origin of which shall be known, and the freedom from adulteration guaranteed by the Department. This is indeed an ambitious scheme and one of which chemists in particular will cordially approve.

I propose, therefore, to give you an account of the work which has already been carried out, and the difficulties which have to be overcome, and then to describe to you the various resins of which samples are before you. Before doing that, however, I would like to bring before you the broader aspect of the case which I had in mind when I contemplated a Paper on Empire Resins. We do not realise sufficiently in this country how great an amount

of effort and how much highly specialised knowledge and skill is being put into the great task of Empire building. With our highly complicated and efficient system of transport and supply we are rather apt to forget all that is involved in the provision of those materials which are essential to our civilisation, but which we receive so easily that we are apt to take them for granted.

We hear much about the importance of buying Empire products, and I would like this Paper to be considered as a demonstration that strenuous efforts are being made to supply us with the best materials from Empire sources, and that the providers are not merely relying upon a sentimental patriotism to find a market for their goods.

There is also another aspect of the case which demands our attention. The importance of forestry has only recently been realised ; the rapid developments in mechanical and chemical science during the last century have rather blinded us to the extent of our dependence upon forest products. But a little consideration makes it clear that they are becoming more important as time goes on. The enormous demands of the paper trade alone are making serious inroads upon resources which a century ago appeared inexhaustible. In America the indiscriminate destruction of forest land in the quest for rosin and turpentine has resulted in so serious a position that the era of maximum production appears to have passed, and we are faced with the possibility of a serious shortage of these products, at least as far as America is concerned.

In Malaya the rapid development of the tin and rubber industries has been achieved at the expense of an enormous destruction of timber, which is estimated to be of the order of 75,000,000 tons in the last 20 years.

It is the duty of Foresters to conserve so far as possible those forest lands which prove to be of value to the community, and to safeguard them against indiscriminate destruction. The main product of the forest from the economical point of view is timber, and naturally all the work of the Forestry Department is influenced by the primary consideration of ensuring a sufficient supply of it.

At the present time Malaya uses about 5,500,000 tons of timber, of which it produces only about 5,250,000 tons. To produce this it is necessary to keep about 25 per cent. of the country under forest. At present the Forest Office controls about 19 per cent. of the area, but much of this is not productive land.

The forest products, of which these resins form a typical group, are classed together as "minor forest products." We should realise, however, that the word "minor" is of only relative significance ; many of these products are only of minor importance whilst they can be easily and cheaply obtained ; when the supply of them threatens to become insufficient their value is apt to increase. One might quote, for example, the case of New Zealand Kauri, which to-day is eagerly purchased at prices undreamed of a generation ago. It is also to be remembered that the study of these minor products has considerable

bearing upon the problems of conserving and efficiently utilising the "major forest products," and it is often the case that one is not only able to obtain minor products in a better condition, but at the same time to conserve and improve the quality of the trees from which they are obtained.

These aspects of the case have to be borne in mind when considering the subject of resins, and the difficulties with which the Foresters of Malaya are confronted can only be understood if these considerations are remembered.

The history of the Forestry Department of the Federated Malay States and Straits Settlement really began in 1879, when Major McNair, the Colonial Engineer and Conservator General of the Straits Settlements, made a report on the timber forests of Malaya, in which he pointed out that already serious encroachments had occurred, and the formation of a Forestry Department was urgently needed. Little, however, was done until 1883, when Mr. N. Cantley, superintendent of the Botanical Gardens, Singapore, organised a Forestry Department, to which were transferred a number of newly-constituted forest reserves. Various reports were made in the following years, and in 1900 the post of Chief Forest Officer of S.S. & F.M.S. was created, the holder of this office being Mr. A. M. Burn-Murdoch, who had previously worked in India. Since then the organisation has expanded, but there has been little change in its form; at present the Forest Office consists of a Conservator, the Forest Research Officer and an Assistant, a Forest Economist, 5 Deputy Conservators and 15 Assistant Conservators, with 8 Extra Assistant Conservators and 8 Sub-Assistant Conservators, with a subordinate native staff numbering about 570.

It is the object of the Forest Department to balance the conflicting demands of the users of Forest products and those who require land for rubber planting, tin mining and similar activities which are progressing so rapidly in Malaya. They also have to conserve the forests on high land which are essential to the valley below, in that they form a protection against weather and erosion. The question of ensuring the purity of the water supply also comes largely within the work of the Forest Office, since streams and catchment areas are invariably in forest lands.

Before dealing with the particular branch of its activities which interests us this evening, I would like to show you a few slides which will give you some idea of the conditions under which the work has to be conducted.

One of the difficulties peculiar to Malaya with which the Foresters have to deal is that the forests are not homogeneous, that is, they do not consist essentially of one particular type of tree, and it is, therefore, very difficult to frame a policy which involves the exploitation of the products of any one particular species.

The tree which particularly interests us this evening is the Chengal tree (pronounced Ching!), which is not only an important timber tree, but the

producer of the principal resin with which I shall have to deal, namely, 'Damar Penak (pronounced Penna) The rapid development of rubber and tin industries in Malaya has also been largely responsible for perhaps the greatest difficulty with which the Damar Industry has had to contend, namely, the shortage of labour.

In addition to the native Malays there are three pagan races, the Negritos, who originally came from the various islands of the Archipelago, the Sakai, who are probably of Indo-China origin, and the Jakun, who live in the jungle. Apart from these there is a floating population of various Chinese and Indian races almost equal to the native population, and of which the Chinese form almost two-thirds. The Chinese are of special interest to us since the resin trade is largely in their hands, the headquarters being at Singapore, where the various resins from the numerous surrounding islands are collected and graded for the European market. The Chinese, however, do not appear suitable for work in the forests. Several attempts have been made to induce them to do such work, but the results are distinctly discouraging; the coolie knows his value and demands an advance of as much as 100 dollars before he will start work, and then not infrequently he absconds at the first opportunity. This moral weakness of the Chinese coolie has indeed been sufficiently marked to cause a perceptible increase in the price of firewood.

In this connection a very interesting experiment was made in 1924 by the foundation of a settlement of imported Malays at Langkap in Negri Sembilan. I believe that these tappers came from Sumatra. The Sumatrans are in many ways well adapted for this class of work, since they are extremely reserved in their habits, and are, in fact, inclined to be too aloof and cause trouble by their refusal to work in with the local native Headman.

This settlement was very favourably reported upon in 1925, but in 1926 there was a slight set-back. This, however, was balanced to some extent by the formation of a second settlement at Sungai Karangi, also in Negri Sembilan. About 2,000 trees are being tapped by the natives in these settlements.

Under the present conditions the tappers are very much better off than they were under the old licences system, when they sold their product to Chinese factors, receiving only a very small proportion of the proceeds.

At the present time if the natives would work full time at tapping they would make a very respectable income, but unfortunately the Malay, although he has many good points, is not very energetic, and does not see the necessity

(1) "Damar" means a torch. The natives make a torch by mixing decayed wood and bark with oil and powdered resin. The mixture is wrapped in a suitable leaf and bound round with rattan in the form of a cylinder about 18 in. to 24 in. long. The word "Damar" is applied to these torches and the resins used are called "Damar Resins." In the European market the name "Damar" is confined to resins obtained from trees of the *Dipterocarpaceae*, all the members of which secrete resins, though not always in sufficient quantity to repay collection. The Damars differ from the Copals in that they are completely soluble in turpentine, coal tar naphthas, but not in alcohol; whereas the Copals are incompletely soluble in these solvents with the exception of the softest grades of Manila which are soluble in alcohol.

for doing the slightest amount more work than is necessary to obtain the very simple needs of his mode of life.

The temperature of Malaya varies from 75°F to 90°F in the shade, and there is practically no difference throughout the year, and under these conditions perhaps great energy is hardly to be expected.

An increase in wages, therefore, does not improve matters beyond a certain point; in fact, it distinctly retards progress, since the native simply works less.

Turning to the resins themselves, I would like to begin by drawing your attention to a number of areas in the Eastern Archipelago from which important varnish resins are obtained. A very fine series of copal resins is obtained from the Celebes Islands, the best being known as Zambas Manila, which comes mainly from Tenati. The series of "Loba" resins, which are very fine Manilas, come from this region and are graded at Macassar. Papua and Borneo also supply large quantities of damar. Pontianac Damar also comes from Borneo, as well as the very important Pontianac copal which has become very popular in recent years as an oil varnish resin, particularly in America. Batavian damar, which is generally considered the best commercial variety of damar, is obtained from the Dutch East Indies, and another important commercial variety is that from Pedang, in Sumatra.

The great collecting station for the resins of this region is Singapore. The damars of the Malay Peninsula, however, although apparently plentiful, have been comparatively little exploited. Until 1922 they were collected by the natives under government license and most of it found its way to middlemen, mostly Chinese at Singapore. The collectors do not appear to have received a fair proportion of the profits, and naturally the dealers, provided they got sufficient resins, were not interested in the development of Malayan industries. There was no effort to extend the industry to parts of the country where there were large numbers of suitable trees, and an examination of the resins led the Forestry Department to conclude that the best grades were being wasted by being blended with inferior products. In 1922, therefore, the Forest Office commenced work on damars. As a first step the various resins were examined, their botanical origin traced so far as possible, and the best method of tapping the trees without destroying their value as timber was studied. The next step was the selection of those resins which promised to be of the greatest economical value, and the preparation of them in such a way as to be acceptable to the varnish maker. As a result of this work the series of resins which I have before me have been isolated.

Before describing them I would like to give you a short account of the methods of collection and preparation of the two principal varieties, Damar Mata Kuching (Cat's Eye Damar) and Damar Penak. This is best shewn by the series of illustrations which were made from photographs, for which I am indebted to the Chief Forest Officer, Mr. E. Cubitt.



FIG. 1. --A typical Penak Tree. Note the ladder constructed with "Peting" (bamboo spikes) and poles.

Fig. 2 shows a Chengal tree which has been tapped for Damar, and on close examination one can see the Damar exuding from the wounds. In order to

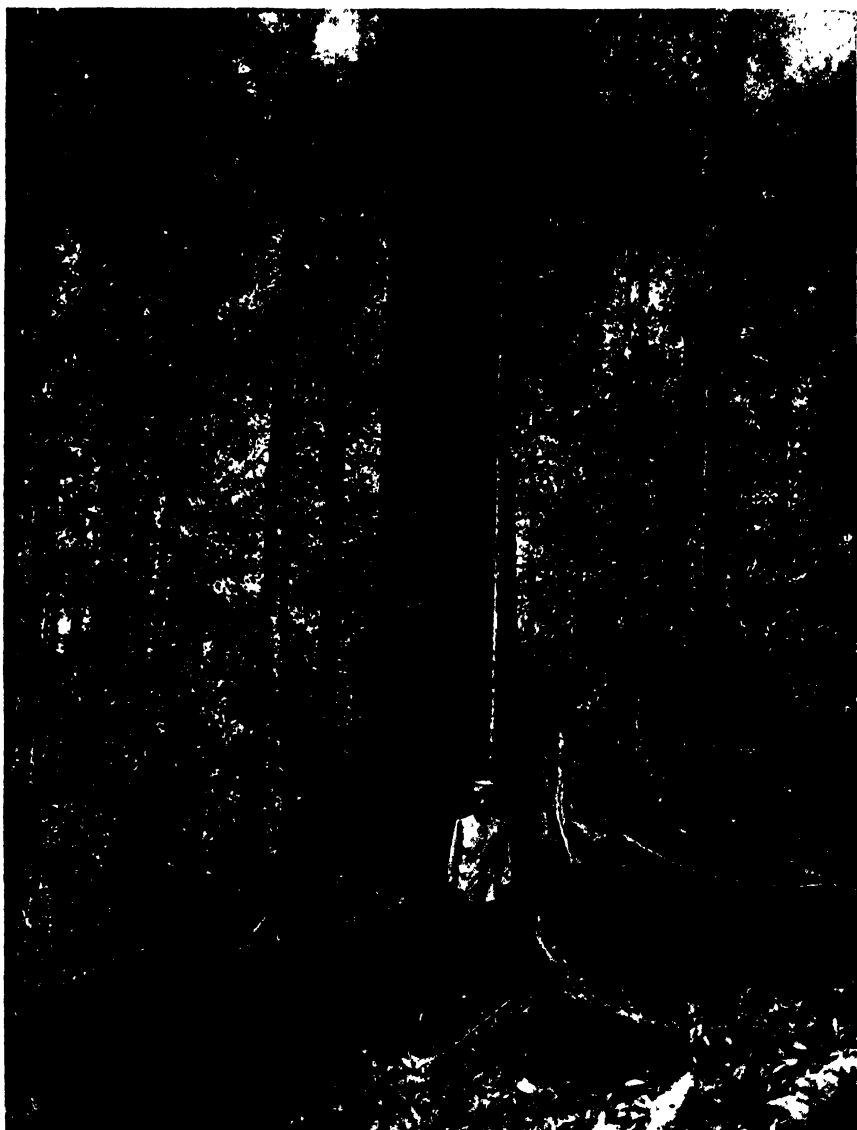


FIG. 2.—Chengal Tree with Taps.

reach the higher portions of the tree the natives climb them by means of a rattan ladder composed of bamboo pegs "peting," or "pesak"² which are driven into the stem with a mallet. This requires some experience, for if they are driven in too far and encounter the heart wood, they are liable to spring out again.

(2) "Pesak" means a peg.

The side of the ladder consists of a "Sengkolok," or climbing rattan, which is made from almost any kind of rattan that is sufficiently pliable. It is preferable to rope, as it can be easily edged up the stem and is very light and strong. The climber ascends the tree and with the aid of an axe cuts his tap holes. Although it appears very light the axe is remarkably strong and springy, so that in the hands of a skilful operator it is a very effective weapon. The iron head is made locally and is fixed in position by wicker work, and can be twisted round in the socket so that it can be used as an adze.



FIG. 3.—Tapping and collecting Damar with a "Behong."

The actual operation of tapping is illustrated in Fig. 3, where the collector is shewn in the act of removing the bark from a new tap hole. It will be observed that the axe head in this case is in its normal position. In the case of the Chengal tree, which is tapped for Damar Penak, the whole height of the tree should be tapped. The tap holes are about 2 feet apart and no tap hole is directly under

another. The bark only is removed, and it is important not to injure the cambium.



FIG. 4. Bridging from one tree to another without descending to the ground. Expert climbers will do this at 100ft. or more above the ground.

In view of the height of the tree, the climber frequently constructs a bridge so that he may pass from one tree to another. An expert climber will pass over such a frail bridge at a height of over 100 feet; in this illustration the trees are not Damar trees, as owing to their height a photograph could not be obtained of a climber on a Chengal tree.

A certain amount of resin is collected by the Sakai and is sold to the Forest Office. The damar is taken to the Government station, where it is washed and sorted into grades. At present Damar Penak and Damar Mata Kuching are sorted into three grades according to colour—pale, yellow and amber. In the case of Penak there are two grades of dust—coarse and fine.



FIG. 5.—Washing Damar Penak.

The washing plant is shown in Fig. 5. The fine resin passes through the sieves and the bark floats away. The coarser resin collects in the settling tank at the far end. The resin is then sorted into various grades according to colour, and finally the damar is sun-dried and packed in boxes.

At the present time about 26,000 trees are being tapped under the supervision of the forestry officials, but of these about 11,000 are only tapped up to 8 feet from the ground, and since a large proportion of the resin is obtained from above that height the amount collected is by no means a maximum, even with the present number of trees.

The collection of the resins from the higher portions is, as you will see, a difficult and arduous proceeding, and there is a shortage of men who will undertake the work. Negri Sembilan seems to be more fortunate in this respect, and it is mainly for this reason that it is from that State that the largest proportion of resin comes.

In 1926 the production of damar was distributed as follows:—



FIG. 6.—Grading Damar Penak.



FIG. 7.—Malayan tapping Implements :—(1) Beliong (tapping axe); (2) Parang; (3) Bamboo Peting or Pesak; (4) Kuehan (bark collecting receptacle); (5) Sengkolok (climbing rattan).

				<i>Reserved Area.</i>		<i>Unreserved Area.</i>		<i>Total.</i>	
				<i>Pikuls.</i>	<i>Dollars.</i>	<i>Pikuls.</i>	<i>Dollars.</i>	<i>Pikuls.</i>	<i>Dollars.</i>
NEGRI SEMBILAN.									
Penak and Mata Kuching...	610.77	24,866	820.14	33,390					
Damar Batu ...	—	120	60.62	45					
Total ...	610.77	24,986	880.76	33,435	1501.53	58,421			
PAHANG WEST.									
Penak and Mata Kuching ...	74.43	453	68.49	3,087					
Dama Batu ...	—	—	52.55	25					
Total ...	74.43	453	121.04	3,112	195.47	3,565			
PAHANG EAST.									
Penak and Mata Kuching ...	91.90	1,457	42.82	958					
Damar Batu ...	—	—	423.59	229					
Total ...	91.90	1,457	466.41	1,177	558.31	2,634			
PERAK NORTH.									
Penak and Mata Kuching ...	123.26	2,980	—	—					
Damar Batu ...	—	—	—	—					
Total ...	123.26	2,980	—	—	123.26	2,980			
PERAK SOUTH.									
Penak and Mata Kuching ...	—	—	—	—					
Damar Batu ...	—	—	8.56	—					
Total ...	—	—	8.56	—	8.56	—			
SELANGOR.									
Penak and Mata Kuching ...	—	—	—	—					
Damar Batu ...	—	—	4176.26	2,088					
Total ...	—	—	4176.26	2,088	4176.26	2,088			
				Total		6563.39	69,688		

It will be seen that the output of Negri Sembilan is much higher than that of any other State. A pikul is equal to 133½ lbs., and a Malayan dollar 2s. 4d. so that the output of Damar Penak and Damar Mata Kuching is about 110 tons, and yields a revenue of £7800, whilst for the inferior damars the figures are 280 tons and £294 respectively. It is estimated that if the resources of the whole country were properly tapped the output could be increased about 10 times. In Perak and Pahang particularly there are large numbers of Chengal trees, but labour is very scarce, and at present the output is low.

Turning to the resins themselves,

DAMAR MATA KUCHING.

This is derived from various species of *Hopea*, and is sometimes called Cat's Eye Damar. The chief tree is said to be *H. Micrantha* Hook. Most of the resin, however, comes from *H. Globosa* Brandis. Other species, such as *H. Inter-*

media King, may also yield this resin, but the botanical side of the question has not yet been fully elucidated. Very little is obtained by systematic tapping. It exudes from the bark of the tree in transparent drops where wounding, either accidental or intentional, occurs.

The resin is very pale and clean. I have here solutions of the different grades in Naphtha and in Turpentine. There is practically no insoluble matter, and the solutions apparently do not change on standing. I have had solutions which have been made up for nearly three years, and do not appear to be any different from when they were made up.

DAMAR PENAK.

This is the chief resin at present dealt with by the Damar Department. It is derived from the Chengal tree *Balanocarpus Heimii* King of which an illustration is given in Fig. 2.

Solutions of the three grades are shown, and it will be seen that the solutions are not so pale or so clear as those of Mata Kuching. They compare favourably however with most of the commercial damars from this region.

A good Batavian damar will give a clearer solution, but the average commercial Singapore damar is more cloudy. I might point out that the cloudiness of a damar solution depends largely upon the method of making the solution. I have here two solutions of Damar Penak which differ only in that one was made by simply shaking the resin with the solvent at ordinary temperatures, whilst the other was made by heating in order to accelerate solution. The solution became cloudy when the temperature reached about 70°C.

Of the others the most interesting are :—

DAMAR SARAYA.

This is derived from species of *Shorea*. It appears to be somewhat different from a true damar, for it does not dissolve completely in the Coal Tar Naphthas. It can, however, be 'run' like an oil varnish resin, and then gives a varnish which although, of course, not pale, is not so dark as one would expect from the colour of the resin.

The name "Saraya" is applied to woods from trees of the *Shorea* species, which is used largely for light furniture, being finer grained than "Merantai," which is also derived from the same species.

Merantai is the most abundant wood in the country, but unfortunately is not durable in contact with the ground. For heavy work, where durability is important, the wood from the Chengal tree is much the best. Owing to the value of the tree as a resin producer its use is being discouraged as much as possible for purposes where these qualities are not essential. It is the standard wood for sleepers and heavy structural work.

DAMAR HITAM AND DAMAR SENGAI.

These appear to have been frequently confused in the past; they are both dark in colour, but the former on exposure to the air rapidly becomes coated with a fine white powder, due apparently to some chemical change, possibly oxidation. Damar Sengai develops no such change.

A great deal of the confusion is due to the fact that the name "Hitam" is frequently applied to the resin from another tree of the *Canarium* species (order *Burseraceae*) which would be more properly described as Damar Sengai. True Damar Hitam³ comes from a tree of the *Shorea* species which is plentiful in Jahore. Sengai, on the other hand, is a much softer resin, and distinctly aromatic in character; in fact is more of the *Elemi* type.

Trees are tapped for Damar Hitam in Jahore, though its local use is not understood. It has a value of from 15-17 dollars per pikul.

DAMAR DAGING.

This is found buried in the soil, and is believed to be produced by a species of *Shorea*, probably *S. Leprosula* Miq., but this is not certain. It is so named on account of its resemblance to a piece of meat, the word 'Daging' meaning flesh or meat.⁴

DAMAR KEPONG.

This is also named on account of its appearance, 'Kepong' meaning a stone.⁵ This resin seems to have excited a certain amount of interest among English resin users, and the Forest Office report large enquiries for it, but, so far, they have not been able to procure enough of the resin in order to fulfil them.

DAMAR KELULOT.

This is interesting, since its origin appears to be rather different from that of the true damars. It is found in the hollows of trees and the nests of a small bee. It is believed that the insects feed upon the resins from certain *Dipterocarpaceae*, and excrete the resin.

DAMAR SIPUT.

This is another resin of similar origin, and is found on the trunks of a tree *Shorea Ridleyana* King.

(3) "Hitam" means black.

(4) "Daging" also means the core or heart of a thing.

(5) "Kepong" also means the surrounding or encircling. Both in this case and in that of "Daging" these alternative meanings may have some significance in connection with their application to these resins, but, it must be remembered that owing to the variety of races in Malaya it is difficult to trace the exact reason for the application of any one term to a particular resin or special implement used by the collectors.

Apart from the damars I have already described, and which are of industrial importance, there are one or two other varieties I would like to mention, because although they are not used to any extent in varnish making, they are certainly of interest.

1. DEAD DAMAR.

Dead Damar is really a modification of Damar Penak, and the reason for its appearance is still somewhat of a mystery. It appears on some Chengal trees when they are first tapped, but sometimes disappears on re-tapping. Apparently immature trees are more liable to give this opaque damar, but I am inclined to think there must be two varieties.

The samples which I have examined were undoubtedly ordinary Damar Penak, the 'milkiness' of which was due to the presence of comparatively large amounts of water, and my results were confirmed by the chemists of the Institute for Medical Research at Kuala Lumpur.⁶

Some samples examined at the Imperial Institute, however, appear to have distinctly different chemical properties from those which were examined by the Medical Research Institute and myself; I am, however, probably giving a full account of this work elsewhere in the course of a month or two, and since the matter is still under investigation, I will not say more about it at present.

2. DAMAR MINYAK.

This is extremely interesting to those who are concerned with the chemistry of resins, for it is the exudation from the same tree *Agathis Alba* (Lamk.) which in the Philippine Islands is known to be the parent of Manila Copal, and which is closely related to *Agathis Robusta*, the Kauri Pine of New Zealand, from which the important New Zealand Kauri Copal is obtained.

For some reason, however, which is not yet understood, the exudation from the Malayan tree does not appear to harden, and consequently the Copal is not obtained.

Mr. A. Suter, our Chairman, informs me that he has in his possession some very fine specimens of Copal from Malaya, the like of which is not to be obtained at present on the mainland. We do not however know whether they were produced in Malaya by the slow hardening or fossilisation of this exudation. It is possible, of course, that they are really of foreign origin, and have drifted on to the mainland from some island.

On distillation the exudation gives about 11 per cent. of an oil which apparently consists of turpenes, and of which I have a specimen that was isolated in my laboratory. The residue is a resin which might be described as of a Manila Copal type. These are, however, still under investigation, and I hope at a later date to be able to give a fuller account of them.

(6) "Notes on Damar Penak." R. W. Blair and F. E. Byron, Malayan Forest Records No. 4, July, 1926.

As things stand at present, there does not appear any possibility of distilling the exudation, though I should imagine, from the experiments I have made so far, that the distillate would be quite suitable for use as a varnish thinner, since it closely resembles turpentine.

DRAGON'S BLOOD.

A small amount of Dragon's Blood is produced in Malaya, and it appears to be much purer than that which is usually shipped via Singapore, and comes from various parts of the Dutch East Indies.

Samples of the Malayan resin obtained from Larut were purified at the Government laboratory, and a product completely soluble in alcohol obtained. Samples of this were sent to England, but curiously inconsistent reports as to the permanence of its colour were obtained, for, whereas one manufacturer claimed that it was not sufficiently permanent, another reported very highly of it in this respect.

The Malayan resin is produced by only one species, a cane named Rotan Jerenang (*Daemonorops Draco*), whereas the resin from other sources comes from a different tree, which grows in the drier parts of Western Asia.

I have in the course of my paper described several resins which are commonly employed by the varnish maker, and some which, although they are not used to any extent, are of considerable potential importance.

I trust that, quite apart from my information concerning the individual resins, I have succeeded to some extent in interesting you in the efforts being made under very adverse conditions to provide us with better materials for our work, and thereby increase our efficiency, and at the same time to forge a fresh link between an outlying part of the Empire and the Home Country. There are many difficulties which cannot be overcome without the close co-operation of the users over here. From the nature of things the Forester is particularly isolated. It is easy to say that it is no use experimenting with materials the supply of which is uncertain, but it is to be remembered that the Forester is equally justified in saying it is no use producing raw materials unless he is certain that there is a demand for them.

Demand and supply are mutually dependent, and I trust that I have done something to inspire those who use these materials, or could use them were they to be obtained, to take a greater interest in this work, and by endeavouring to find the best means of using them, to give the Forest Office some guidance as to the direction of its efforts and some encouragement in its work.

For the past three years I have been in continuous correspondence with Foresters and technical advisers in different parts of the East, and without exception I have found them eager for information as to what we want. Their complaint is always that no one over here appears to take much interest in their materials beyond criticising them adversely, and they would welcome

some constructive advice as to how they should prepare their materials for the English market, and as to what purposes they could best be applied. They are always anxious to know exactly how their materials are incorporated in our manufactured articles, and precisely what we mean by the technical terms we use to describe defects.

Often I have found that the defect which has been so emphatically pointed out to them is one which is common to all materials of that class, and it is not fair to suggest by implication that it is possible to obtain a material of the type in question which does not possess that defect.

Damars, for example, are admittedly soft resins. The varnish films obtained from them are inclined to be tacky, and generally their solutions are apt to become cloudy or even precipitate on keeping. But this is common to all damars, and therefore it is hindering, rather than helping, the Forest Officer to make this complaint as if it were peculiar to his product and not common to the whole family.

In conclusion, I would like to take this opportunity of thanking the numerous friends who have helped me in the collection of materials.

I am specially indebted to Mr. E. Cubitt, the Chief Conservator of Forests F.M.S. and S.S., and Mr. V. G. Bell, Assistant Conservator, now at Forest Kedah.

I have also to thank Mr. J. F. Owen and Mr. H. Banner, of the Malay States Information Agency, not only for the trouble they have taken to give me correct information, but also for the coloured slides which I have shown, and some of the specimens.

I would like also to thank Mr. Suter for presiding this evening, for he is not only one of our leading Gum Merchants, but has a great enthusiasm for the development of purer and better grades of resins, and has been a great help and inspiration to me in my work. I feel, therefore, that no one could have been more fitted to take the Chair this evening.

DISCUSSION.

MR. M. D. CURWEN (Editor of *The Industrial Chemist*) thanked the lecturer for his instructive lecture, which served to illustrate what bright spots both the F.M.S. and the Straits Settlements were in the British Empire. Personally he desired to deal with the subject from the forestry point of view. One got an inkling from the lecture that the Forestry Department in Malaya were in conflict with other branches of industry, namely, the mining industry, and probably the fuel industry. That was so common in many other countries, and in conjunction with forest products, that he would like a little information on what was proposed, not only from the conservation point of view, but also from the re-afforestation standpoint. There were object lessons to be learned in the matter by looking at the position in Canada and Australia. Personally he had had a little experience with regard to two particular products in those two Dominions. The first of those products was wood pulp. One could take the view, in regard to Canada, that in about 30 years' time

there would be more or less a complete famine in wood pulp. What that would mean to the newspaper industry could easily be realised. One could visualise *The Times* as a monthly publication and *The Evening Standard* as a weekly, and, what might be of more interest especially to the ladies, there was the fact that artificial silk stockings might go up in price. With regard to Australia, it was rather an extraordinary fact that the wattle—of which Australia was the home—had more or less disappeared from that Dominion, from an industrial point of view. The wattle produced extraordinarily fine bark and bark extracts for all the tanning industries, but nowadays Australia did not produce sufficient even for her own needs. The industry had gone over to Natal and to certain parts of South Africa. South Africa now exported practically all the wattle produced in the world. Coming back to his original question, from which he was afraid he had wandered, he would like to ask the lecturer if there were any possibilities of reafforestation of gum trees and resin trees in the F.M.S.

MR. A. A. DRUMMOND said he had listened with much interest to the lecture. He was not qualified to contribute anything to the discussion of Malayan damars or natural resins, but he would have liked the lecturer to have dealt more fully with the mechanical and physical side of the resin question.

MR. H. W. MORGAN said he was glad to have the present opportunity of thanking the lecturer, on behalf of members of the trade, for the extremely interesting lecture he had given. From the gum merchants' point of view, trade had very little romance in it, but when they attended a lecture such as the present they began to see that there was a great deal of romance in it. It did not consist only of dust and dirt, such as the poor gum merchant had to put up with, but it had a very romantic origin. The trade had learned a lot from the lecture. From the trade point of view the Malayan damars were the newest. When the trade first started the chief damar had been Batavian and Pontianac. Those two damars were entirely different in character and had to be kept quite separate. In Malaya there were two damars—the "cat's eye" and the Penak. The latter, from the trade point of view, had without doubt the greater value. It was fetching a better price than any other damar; in fact, it was pushing Singapore almost out of use. It was miles above Batavian in value, and it was certainly very favourably received by the trade. It was a good damar, and was so beautifully blended and graded that it was taking a very favourable place indeed. The trade could do with more of it. If these remarks would encourage those on the other side to send more of it, the trade would be very glad to receive it. With regard to black damars, the first sample of black damar which had ever been received in London had come with the useful information that the natives used it to caulk their boats. That was the purpose for which it was usually used on this side, and a huge business had been done in it. The genuine black damar was one which had certainly made its mark.

DR. W. RUSHTON PARKER enquired why it was that the whole of the east side of Malaya was not opened up for the growing of damar trees. He would also like to enquire what was the use of the damar to the tree itself. Why did the tree grow damar? No tree grew anything merely for human beings' benefit; it only grew it for its own benefit.

MR. H. W. MORGAN asked if the lecturer could state at about what age the tree began to produce damar so that it could be tapped? If it was a matter of 30 years or so before the tree could be tapped, any planted now would be of very little use to the present generation.

MR. H. T. ISLIP said the lecturer had referred to grading by colour. 'Was there any grading by size?' With regard to the question of moisture, the lecturer had referred in that connection to so-called dead damar. Personally he was not at all certain that the trouble was entirely caused through moisture. He understood that the whole exudation of dead damar was abnormal, and he understood it was obtained only from immature and badly-tapped trees.

MR. A. F. EVANS asked if Hindu labour could not be employed for damar collecting. Such labour was generally used in the rubber industry.

MR. ARTHUR JAMES CASTLE asked for which type of varnish damar resins were used, and for what class of work was the varnish used which was produced by damar resins in the painting and decorating trade.

THE LECTURER in replying to the various questions raised said that the answers to many of them would be found in the text of the lecture when printed. This was particularly so in the case of afforestation to the importance of which Mr. Curwen had drawn attention.

He was very glad that this aspect of the subject had been raised and he fully agreed with Mr. Curwen as to the folly of adopting a short-sighted policy in this matter.

Some details were given in his written lecture concerning the present position of afforestation in Malaya and the policy of the Forestry Department.

In reply to Mr. Curwen's remarks on paper, it might be interesting to refer to the experiments which had been made at Kuala Lumpur on various materials.

The two chief possible raw materials were Lalang Grass (*Imperato Spp.*) and Bamboo. The former was quite a pest in some parts owing to its rapid reproduction, but unfortunately the areas it covered were very liable to invasion by other less suitable plants, and consequently careful sorting of the product was necessary to ensure consistently satisfactory results and this naturally increased costs, especially as labour shortage was already a serious item in the Peninsula.

It was also very bulky and it would be necessary that the factory should be near a plantation which would have to be about 10,000 acres in extent, and it was doubtful if such an area was available.

Bamboo gave an even better paper and there was a possibility that one factory at least, could be worked economically in a suitable area which in this case would need to be only 3,000 acres in extent. Such an area had not yet been fixed upon, but it was within the realms of possibility.

The other raw materials of paper making would have to be imported, and on the whole it must be admitted that in the present state of our knowledge prospects for the paper industry in Malaya were not very hopeful.

With regard to the reservation of forests it was important to realise that reservation *did not* mean that productive work in the area was prohibited. It really meant that before anyone was allowed to cut down the trees he was required to produce evidence that his object was such as to justify the destruction of the timber, and that he was competent to carry out his schemes. The system also gave the Forest Office a chance to supervise the felling of the timber and to dispose of it in the best possible way. The Forest Office was also able to encourage cultivators to take up the land which was the least valuable from the point of view of forest products. There was naturally at times considerable conflict between the Forest Office and those who wished to exploit the area for other purposes, but, on the

whole, the policy of the Forest Office had been justified, and more than 70 per cent of the timber produced came from Forest reserves. Apart from their work in the Federated States, Forest Officers were also loaned to the Unfederated States at the request of the Native Sovereign, in order to safeguard forest lands and improve the exploitation of the products, and this in itself was proof that its policy was found to be a wise one by those who were in a position to judge.

Another important branch of the Forest Officer's work was the study of the lesser known timbers with a view to encouraging their use in cases where the properties of the more valuable timbers were not essential. In this way it was hoped to conserve so far as possible such trees as the Chengal tree which was valuable not only on account of its Damar production, but, also because its timber was the standard wood of the country for heavy structural work and for sleepers.

As regards the cultivation of the resins themselves, Dr. Rushton Parker had referred to the fact that although the Damar trees were to be found all over the Peninsula, the collection of resin was apparently confined to a few areas mainly on the East Coast. This was certainly the case at present, but the main trouble was the supply of labour and in his written lecture he had dealt with this aspect of the question more fully.

Mr. A. F. Evans had referred to the possibility of using Hindoo labour; that matter was at present under consideration, and it was proposed that a Forest Officer from Southern India should go to Malaya to study conditions with a view to importing forest dwellers from South India for work both as resin collectors and general forest labourers.

With regard to the resins themselves, he quite appreciated Mr. Drummond's desire for more knowledge on the chemical aspects of the subject, but he would point out that he had already given an account of the general characteristics of these resins before the Oil and Colour Chemists' Association (J. Oil and Colour Chem. Assoc., 1925, 8, 204), and that he was due to make a further contribution to the same Association in February next year. Quite apart from that, however, it would seem that until the origin and nature of the individual resins was understood there was little to be gained by chemical analysis; in fact, these specimens of inferior Damars really represented the primary analysis of a product which came over here under a single label, but was really a mixture of these individual resins. We could not hope to correctly interpret our chemical data unless we had a detailed knowledge of the ingredients of our material.

The work of the botanist and forester therefore was an essential preliminary to chemical work.

These remarks also applied to some extent to the question of Dead Damar, to which reference had been made by Mr. H. L. Islip. The subject was discussed rather more fully in the written lecture and at the moment he did not wish to say any more about it, beyond the fact that in the case of the Dead Damars he had examined there was no doubt whatever that water was the cause of the trouble. At the same time, it was quite possible that a product similar in appearance might also be produced under other circumstances, and that this differed in chemical properties from that which Mr. Blair, Mr. Byron and himself had examined.

He (the lecturer) had been particularly interested in some of Mr. Morgan's remarks during the interval, for, he had identified several of these inferior Damars as being ingredients of ordinary commercial Black Damars, some of which were undesirable and some of which might be of more value were they sold separately. That indeed was a most important contribution and very encouraging, as it strongly supported the hypothesis on which the work in his own laboratory was being conducted;

namely that a true understanding of these individual resins was necessary before one could really proceed to make definite statements as to their relative importance in industry, and the significance of certain variations in the commercial material in use at present.

Mr. Morgan had raised several other interesting points, but at the present time he (Mr. Hedley Barry) was unable to give any information about the age at which a tree was mature from the point of view of Damar production. These trees were very large and doubtless took many years to mature, but they had only been under close observation from the point of view of Resin production for about 6 years. Mr. Morgan's praise of the Damar Penak and Mata Kuching was very welcome. It had been extremely difficult to get recognition for the Malayan Damars. A few years ago the Forest Office got little or no encouragement, and the lecturer had often felt that his own work on these resins was wasted so far as the varnish industry was concerned. That so experienced a Gum Merchant as Mr. Morgan should speak so optimistically of their future was indeed proof of a remarkable change in the attitude of the users of these resins, and it also showed that when the English manufacturer seriously attempted to use a new material he could succeed as well as any.

Mr. Morgan had referred to the use of these inferior resins by the natives of Malaya in caulking their boats. It might be of interest to describe the process. The powdered resin was mixed with chopped gunny-bags and Keruing Oil and ground in a mortar, boiling water was then added and the whole ground up to a sticky mass, which was applied with the fingers to the seams of the boat which had previously been stuffed with gunny-bags. In order to prevent the preparation from sticking to the fingers they were smeared with cocoanut oil.

Mr. Morgan would be doing a great service if he would communicate his remarks on these resins direct to the Forest Office.

With regard to the question of grading resins, the Forest Office had made great efforts to obtain accurate information as to the desire of the trade, and were it desired that the resin should be graded according to size no doubt this could be done, but, so far it appeared that grading according to colour was sufficient.

In the case of Damar Penak the smaller pieces are graded to some extent according to size:—"Kachangs," the size of peas:—"Nibbles," slightly smaller:—"Coarse Dust," small granules:—"Fine Dust," a powder.

The first three were quite satisfactory for varnish making, but, the fourth presented some difficulties due to the fact that the impurities were extremely fine, and it was difficult to separate them from the varnish. It was probable however, that the use of one of the numerous varnish separators now on the market would effectively solve this problem.

There were further objections to the fine dust in that it was naturally more liable to oxidation and other atmospheric effects, and also there was in the resin industry a very natural prejudice against powdered resins imported from the East as they were so liable to adulteration. In the case of Dragon's Blood, for example, consignments had sometimes been received containing as much as 30 per cent. of adulterant, and their experience with this and other resins had naturally made both users and merchants very chary in their reception of powdered resins. In the case of the product of the Malayan Damar Department, which was packed in cases containing a Government guarantee, this suspicion would probably be easily overcome once it were found that it was of value and there was a good market for it.

Samples examined by the lecturer had contained about 5 per cent. insoluble matter and this was not exceptionally high for low-grade Damars.

One other point might be referred to, namely, Dr. Rushton Parker's query as to the production of resins by trees. This was still an unsolved problem. It appeared that it was a means by which nature provided the tree with an emergency coating for an exposed tissue.

Some interesting work had been done on the relationship between the formation of aromatics and carbo-hydrates in trees, and it was known that the resins were all of an aromatic nature as distinct from the gums which were carbo-hydrates. This, however, did not help us much, for both resins and gums were used by trees to protect wounded areas. One might also refer to the elaborate researches in America and in India on the variation in the rate of flow of resin from the trees. The subject had been most fully studied in connection with the Turpentine and Rosin industry, but, even there the problem was far from being solved. The distribution of the resin ducts in trees varied considerably. In the case of the pines for example, one obtained a satisfactory yield of resin by merely making a blaze on the lower portion of the tree trunk, but, in the case of the damars it was necessary to tap the whole surface of the tree; again in Malaya, it was important not to wound the cambium of the tree and the resin exuded from between the bark and the cambium. In Sierra Leone on the other hand, the copal trees had to be tapped by puncturing both the bark and the cambium, and the resin exuded from the cambium region. Evidently then there was a wide variation in the way in which resin was secreted and much research work was still necessary.

In conclusion, the lecturer wished to thank the audience for their attention. He had endeavoured to deal with his subject in such a way as to give it a living interest, and he had been guided by the clause in the Charter of the Royal Society of Arts which described one of its aims as being to foster means of communication and trade between the various parts of our Empire and to increase the knowledge of its resources and possibilities of development. This particular branch of activities was admittedly only a small one, but, it was an important one and typical of the work which was being done in all parts of the Empire, and he hoped that he had contributed something towards fostering an interest and enthusiasm for the development of Empire trade and products.

THE CHAIRMAN said it could easily be seen that the more questions were asked the further and better information the lecturer gave, and it was with regret that he had to declare the meeting at an end. He himself had not much to say. The damars, of course, were only one group of the natural resins—and one of the smaller groups at that. It was very peculiar that, taking the East Indian Archipelago, working from west to east, one came across the damars—in Sumatra, Java and in Malay, and partly in Borneo. As one went east through Celebes, Malacca and the Philippines, it was not damars which were obtained from there, but copals; and the curious thing was that on the east coast of the Malay Peninsula and in portions of Borneo there existed a whole mass of bastard gums which were neither copals nor damars, but which showed the properties of either or some of them; and it was particularly with regard to those, which had so far not been exported, or at least only very insufficiently that interest lay. Returning to damars, the Forestry Department in the Malay Peninsular had found a most excellent spokesman in the lecturer. They in the trade often said "What can the Government do for us? they simply hinder us; they ask questions and want to know things." But it was exactly lectures like the present which brought it home to them that they were mistaken. They in the trade, if they were allied more closely to those in authority and if they looked to the authorities for more help, would probably get on quicker than they did. There was in the shellac trade a

very analogous movement going on at the moment. There were troubles in that trade too in India, and the Government had now opened a research department which was expected to help the trade, and which he was convinced would help it. In the Malay Peninsula the Forestry Department had been doing very good work. They had, for instance, shown that resins from certain trees could be isolated and brought to Europe and definitely standardised. There were good damars from Sumatra and from Java and from Borneo, but they never came from one plant only. The present was the first attempt at standardisation, and it was an attempt, as far as he could see, which was going to help very greatly and which was going to succeed. The getting of resin might be likened to the getting of milk from the cow. As long as the cow had not been domesticated she had produced only enough milk for her calf. Then man, when he had tasted the milk, had said, "This is a good thing and we want more of it," and as he went on milking he got more milk; he even pushed the calf aside at times and got the lot himself. He had been glad to hear Mr. Morgan's appreciation of the efforts which were being made. Those efforts cost money. They were undertaken by unselfish men with big ideas and tremendous energy who very often come home broken in health, and who sometimes felt as if they had done no good; but the collective effort of such men under Government supervision was very great and bore fine fruit.

A hearty vote of thanks to the lecturer for his instructive address concluded the meeting.

CORRESPONDENCE.

"ROAD TRAFFIC PROBLEMS OF THE PEDESTRIAN."

May I comment on Colonel O'Gorman's lecture on the above subject?

I would like to enlarge on the two points raised by Colonel Pickard—the problem of the rural pedestrian and the fact that excessive speed is by far the most outstanding cause of all fatal accidents, on both of which he would be supported by an enormous percentage of the users of roads. But he made his case quite clear, and Colonel O'Gorman's answer was scarcely relevant and far from convincing.

The one point which no one seemed to have criticised, except so far as Colonel Pickard laid stress on "the relative," was the worthlessness of Colonel O'Gorman's figures (p. 39 of your issue). They are quoted as percentages, but are not real percentages in the least, because he ignored the totals under each heading. When we know how many drivers were convicted for being sufficiently foolish, selfish and reckless to drive over 20 m.p.h. in London, we can say what their percentage of maiming and killing was. If 100 such men were convicted, their percentage was 45, not 4.5. If the drivers who were unlucky enough to have accidents, though not exceeding 10 m.p.h., were 10,000, their percentage was not 36.5, nor even 20, but 5.7.

So, too, with regard to the statement (p.40) that pedestrians were a far more frequent cause of danger than dogs. Until we know the totals of both pedestrians and dogs (not on the lead), such a statement is as worthless as it is reckless.

It would be a profound blessing if Colonel O'Gorman's admirable suggestions could be enforced on pedestrians; but he only ruins what might be a perfectly sound case by using statistics which any pedestrian can easily prove to be perfectly worthless.

L. W. LYDE.

ROYAL SOCIETY OF ARTS EXAMINATIONS.

Will you allow me again to bring before the notice of the Fellows of the R.S.A., the very valuable comments of the examiners in the *Journal*, as for instance, *Arithmetic* (p. 1211): "Enough attention is not given to the decimalisation of money."

If 3,638 candidates failed in *Arithmetic*, the fault lies with the Board of Education which will not allow us to use the decimal coinage which we have already. Nature has provided man with five digits on each hand, which is the basis of calculation by tens. The Government decides that we have, or should have, 12 fingers and must calculate accordingly. Hence the waste of money, nervous force and time in elementary schools, in learning and practising the pence table.

English (p. 1211): "As usual in English in Stage I, there were a considerable number of candidates who were below any reasonable examination standard."

"The spelling was occasionally deplorable."

Shorthand (p. 1212): "Most of the mistakes would seem to be due to limitations of general education."

"Mis-spellings such as tobacco and tabbioco for tapioca, and various versions of 'syndicalism.'"

Economic Geography (p. 1213): "'Norwich' spelt 'Norige,' etc."

Typewriting (p. 1213): "The work of many candidates was marred by extraordinarily bad spelling."

Here again the Board of Education is to blame. Elementary education is simply a four years course in "Printing Errors," and as long as the Government neglects to supply school books logically printed to be read *out loud*, so long shall we remain handicapped by our irregular spelling. A headmaster of a large school in Birmingham writes: "Of course we do not impugn the merits of Orthotype as applied to the solution of very many problems, but until it has received the imprimatur of the Board of Education, it is more than difficult for schools to use it." Hence the want of commercial travellers.

Advertising and Salesmanship (p. 1217): "Some candidates showed an ignorance of grammar and spelling that is quite unpardonable in an advanced student."

French (Stage I): "While some candidates were able to answer the questions on the irregular verbs quite well, they made impossible blunders when they came to apply their knowledge."

Does this not show clearly, that the "blunder" is in teaching irregular verbs, instead of using the more natural phonetic direct method?

A. DEANE BUTCHER, F.R.S.A.

NOTES ON BOOKS.

THE ARCHITECTURE OF THE RENAISSANCE IN FRANCE. By W. H. Ward. 2 Vols. Batsford. 21s. each.

Mr Ward's book, here in its second edition, makes excellent reading. The author had great knowledge, not of his enthralling subject only, but also of French history, and his account of architectural development is enhanced by the relevant historical details which he introduces. It is a pity that in printing the book an unattractive foreign type face has been used, and that it was composed on a machine incapable of properly spacing the short lines beside inset illustrations.

The poet claimed too much when he addressed his country as "*mère des arts, des armes et des lois*," for the arts were certainly born, and re-born, beyond the Alps; but France proved a wonderful foster-mother. Mr. Ward describes the amazement of the French nobles and gentlemen who accompanied Charles VIII on his celebrated expedition, upon their beholding the first fruits of the Renaissance, the palaces and ornaments and sunny gardens of Italy. Early in the next century Italian influences began to show in French building. At the start, Italian detail replaced Gothic; soon members carrying weight and encircling space were taking on Renaissance forms.

That the new movement in France went through an important transitional stage was due to the firm hold which Gothic had there, the case of Italy having been quite different. Chambord is sometimes regarded as the masterpiece of the French mixed style, which can also be studied at Blois, in the older parts of the castle. And on the whole, Gothic and Renaissance elements supported each other remarkably well. Later, architecture in France became less picturesque, and in a sense less characteristically national, but more classical and dignified. Indeed, the French architects worked wonders with classical forms, and one of them, by a touch of original genius, even succeeded in giving new life to the ancient Roman triumphal arch. This was François Blondell, whose *Porte St. Denis*, in Paris, is infinitely superior to the much larger and more famous *Arc de l'Etoile*.

Owing to the fact that the Renaissance style was an acquired taste, a taste, moreover, acquired in the first instance by the nobility only, churches took much longer than palaces to shed the Gothic influence. They had done so by the time that the younger Mansart had come to the fore. This architect was responsible for the dome of the Invalides, a delicate, beautiful, but rather sensuous structure. The elder Mansart's name is perpetuated in the admirable type of urban roof which he popularised, of which Lescot, however, seems to have been the inventor. This device of flattening roofs was one of the steps away from mixed Gothic and Renaissance towards a purer classical style. François Mansart was not only an architect of the highest talent but a man of principle as well. Rather than be false to his artistic criteria, he threw up the most important post open to an architect in France.

Gradually the French evolved styles perfectly suited to the practical and aesthetic requirements of a western European town. The *Place Vendôme* was built in 1699. The twin palaces in the *Place de la Concorde* were the work of Gabriel, the man who modernised Bordeaux. Later again came the *Rue de Rivoli*, of which the authors were Percier and Fontaine, who were patronised both by Napoleon and the restored Bourbons. These two were also among the brilliant galaxy that helped at different times to build up the Louvre.

RIGHT MAKING. By B. J. Fletcher. Design and Industries Association. 6d.

Many readers of John Stuart Mill's "*On Liberty*" have reflected with sorrow that it is not so easy to carry out as to formulate reasonable social principles. Much in the same way might readers of Mr. B. J. Fletcher's pamphlet lament that a clear understanding of the three fundamental principles of design which he here expounds should not enable the craftsman of talent to do good work. Alas! it is not by itself enough to be a little reasonable and a little talented to succeed as artist or craftsman.

In discussing the first of the three principles, *fitness for purpose*, Mr. Fletcher says: "The beauty of the perfect forms of natural things comes of necessity." What sort of an argument is this? Theological, biological, mechanistical? It

might have been better to say, simply : tables must be steady on their legs, knives must be sharp enough to cut with, etc. Then, unfortunately, the point is illustrated by two photographs of display types, both of " Broad Walk " signs outside Kensington Gardens. One is supposed to be more legible than the other. I find I am not alone in regarding the two as equally legible, though I am sure the one is handsomer than the other. Legibility, or fitness for purpose, is not here the secret of attractive design.

We come to the second principle : *that the thing shall be suitable in design for the material of which it is made.* Two chests of drawers are shown, one apparently a very fine example of French eighteenth-century craft, the second plain and uninteresting, with too much made of the grain and natural quality of the wood used, in the characteristically modern style. Mr. Fletcher's praise is all for the latter. What does it matter if it " comes as a surprise to discover that this (the former) is a chest of drawers and that the loops of dragons and their tails are handles ? " The distaste for illusion here manifested is a curious temper in which to approach art. One might as well hate the column for not more exactly reproducing the tree trunk, its ancestor.

In addition we are asked to compare one of Landseer's Trafalgar Square lions with an Egyptian lion of the time of Tutankhamen. The lion of antiquity is vastly superior to the other. Agreed. But Mr. Fletcher's account of why this strikes me as quite misleading. The Egyptian lion is indeed so unrealistic that if anyone claimed it for a tiger it would be hard to argue the point. But if it comes to that, a child going to the Zoo for the first time will be horribly disenchanted if it bases its expectations of real lions on those in Trafalgar Square. The secret of ugly design, in this case, is not excess of realism.

The third principle—*that a design shall be fit for the tools which are to be used*—" needs little emphasis," says Mr. Fletcher. It could stand more emphasis if once again the cart were not before the horse. The following passage is only too true. " We have to turn to mediæval woodcarving to appreciate the masculine vigour of crisp and surely-cut carver's work. In carving, as in other crafts, we are not satisfied now unless evidences of the tool are sand-papered or smoothened. This desire for lifeless and characterless smoothness, and for a certain superficial smartness and shiny finish, is the bane of most modern work."

THE ARCHITECTURE OF THE RENAISSANCE IN ITALY. By W. J. Anderson and A. Stratton. London : B. T. Batsford, Ltd. 21s.

" It has been said," wrote W. J. Anderson, " that in Brunelleschi's hands the architecture of the Renaissance had a Tuscan or provincial character, while in the hands of Alberti it became more Roman ; and it may fairly be claimed that if Bramante went further and rendered it national . . . Peruzzi, Sanmicheli, an ultimately Palladio made it European." Incidentally, what a catalogue of illustrious names ! And even if we add Michelangelo, Sansovino and Vignola we shall not have exhausted the list of masters who were the glory of that astonishing age.

Though Brunelleschi had prepared himself for his life's work by close study of ancient Roman buildings, his dome in Florence has not a characteristically Renaissance look. On the other hand, his Pazzi Chapel in Santa Croce has been well described as a sort of spring flower of the revival. Here, at the outset of the movement, it should be clear that the tendency was not to copy but to develop the ancient Roman style. Alberti, one of the most remarkable individuals of all

time, did not allow his immense erudition to kill spontaneity, nor even to keep him too strictly in the Roman tradition, for, as Anderson himself points out, the main features of the beautiful porch of the Church of Sant' Andrea at Mantua are an anticipation of Palladio. In an earlier work, Santa Maria Novella in Florence, Alberti introduced "the use of scroll forms for connecting the lines of nave and aisle walls," a device which, in Anderson's opinion, "was carried to excess in later Roman churches." Anderson was not a friend of the Baroque: In the first edition of his book occurred this sentence: "The Barocco style, despite its untruthful and unprincipled character, seems to have its use in expressing ostentation and bombastic pomp." Mr. Stratton has added an interesting chapter in the present edition, purposely to do justice to the "Barocco style," which both in Italy and abroad scored triumphs that in the second half of the nineteenth century it was the fashion to under-rate.

The grounds for stating that Bramante "rendered (the Renaissance style) national" are his ingenuity and power of assimilation; perhaps he had not quite the originality of Brunelleschi or Alberti, but he certainly knew how to improve on some of their ideas. Thus the Cancelleria Palace in Rome is an advance on the very similar Rucellai Palace in Florence, largely owing to a better disposition of the pilasters. It was indeed an age of almost embarrassing richness where genius was concerned. That Michelangelo should have been able to turn from painting and sculpture to designing such a magnificent façade as that of the Museo Capitolino must always remain a matter for awe. And though Raphael has not left a great quantity of buildings (any more than Leonardo has left many pictures), his architectural legacy is exquisite. A fine example here illustrated is the Palazzo Pandolfini in Florence.

Peruzzi introduced a Greek element into his work, and Sanmicheli fused the local Venetian and the more broadly Renaissance styles, thus producing such a masterpiece as the Palazzo Grimani. Venice also owes much of its beauty to Jacopo Sansovino, about whom Vasari and Ruskin hold such different views, and who probably at moments came closer to ancient Roman ideals than any of his forerunners, except in certain cases Vignola.

For several reasons, not all valid, Palladio is commonly regarded as the chief exporter, so to speak, of the principles of Italian Renaissance architecture. His merits are nowhere denied. His style varied a good deal. Compare, for instance, the Palazzo Comunale at Vicenza, where the order is carried through the whole height of the building, with the Palazzo Chiericate in the same city, which has a separate order for each storey; and compare these again with the Church of San Giorgio in Venice.

The arts, and the art of architecture in particular, never flourished more than in the first half of the sixteenth century in Italy.

P.B.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, DECEMBER 19. Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Dr. Reginald Miller and Mr. J. Ernest Franck, "Some Medical Aspects of Damp in Dwellings."
Geographical Society, at the Aeolian Hall, 135, New Bond Street, W. 8.30 p.m. Captain W. S. Kirby, "Johore in 1926."
Swiney Lectures, at the Royal College of Science, South Kensington, S.W. 5.30 p.m. Dr. Robert Campbell, "The Geological History of Scotland." Lecture IV. "The Dalradian Schists and the Moine Schists."

University of London, at King's College, Strand, W.C. 5.30 p.m. Maj.-Gen. Sir Frederick Maurice, "Principles of Strategy." (Lecture III).

TUESDAY, DECEMBER 20. Photographic Society, 35, Russell Square, W.C. 7 p.m. Demonstrations of New Apparatus.

Statistical Society, at the Royal Society of Arts, Adelphi, W.C. 5.15 p.m. Mr. L. R. Connor, "Certain Aspects of the Distribution of Income in the United Kingdom in the years 1913 and 1924."

WEDNESDAY, DECEMBER 21. North-East Coast Institution of Engineers and Shipbuilders, Middlesbrough. 7.30 p.m. Mr. R. F. Battey "The Progress in Diesel Design."

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FRIDAY, DECEMBER 23rd, 1927.

*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C.(2.)*

NOTICES.

COUNCIL.

A meeting of the Council was held on Monday, December 12th. Present :— Sir Philip Magnus, Bt., in the Chair ; Sir Charles H. Armstrong ; Lord Askwith ; K.C.B., K.C., D.C.L. ; Sir Charles Stuart Bayley, G.C.I.E., K.C.S.I. ; Mr. Peter MacIntyre Evans, M.A., LL.D. ; Sir Alexander Gibb, G.B.E., C.B. . Sir Robert Abbott Hadfield, Bt., D.Sc., F.R.S. ; Rear-Admiral James de Courcy Hamilton, M.V.O. ; Sir Arthur Holbrook, K.B.E., M.P. ; Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S. ; Major Sir Humphrey Leggett, R.E., D.S.O. ; Sir Reginald A. Mant, K.C.I.E., C.S.I. ; Sir Richard Redmayne, K.C.B. ; Sir George Sutton, Bt. ; Mr. J. Swinburne, F.R.S. ; Mr. Alan A. Campbell Swinton, F.R.S. ; Mr. Carmichael Thomas ; Sir Frank Warner, K.B.E. ; and Sir Alfred Yarrow, Bt., F.R.S., with Mr. G. K. Menzies, M.A. (Secretary), and Mr. W. Perry, B.A. (Assistant Secretary).

The final arrangements for instituting a Staff Superannuation Scheme were considered and approved.

An offer from the Hon. Sir Charles Parsons, O.M., K.C.B., F.R.S., to defray half the cost of a Ross Kinematograph Projector was gratefully accepted.

An offer from Mr. James H. Hyde to provide a Travelling Scholarship of £100 in connexion with the Sections of Architectural Decoration and Textiles in the Annual Competition of Industrial Designs, 1928, was gratefully accepted.

The following candidates were duly elected Fellows of the Society :—

Adams, Bernard, London.

Aird, Reginald James Mitchell, London.

Alexander, George Edward, Churt, Surrey.

Badham, E. Leslie, R.B.A., St. Leonards-on-Sea, Sussex.

Barratt, Stanley George Reeves, Kings Langley, Herts.

Bates, Sidney, Prudhoe-on-Tyne.

Beatty, Alfred Chester, London.
 Beaufort, Thomas Richard, London.
 Bradshaw, Hubert, Ilkley, Yorks.
 Brown, Reginald Busby, London.
 Bulgin, Arthur Frederick, London.
 Clarke, Robert Coningsby, London.
 Dearle, John Henry, London.
 Dunn, Professor Frank Ambrose Stewart, Edmonton, Alberta, Canada.
 Edgar, Captain Walter Herbert Adgey, London.
 Fermery, John, M.B.E., Ilford, Essex.
 Gibbins, John, Birmingham.
 Gill, Hubert A., M.A., London.
 Gregory, Patrick Bernard, Belfast.
 Hetherington, Robert, Perth, W. Australia.
 Lawrenson, Mrs. Charlotte, Hadley Down, Sussex.
 McCulloch, Herbert Graham, Norley, Warrington.
 Menzies, James Joseph Walter, London.
 Mozley, Henry, Burnley.
 Oliver, Basil, F.R.I.B.A., London.
 Pavière, Frederick Leslie, Oxford.
 Perrin, James Frederick, A.M.I.E.E., London.
 Reid, Allan Douglas, London.
 Revell, Thomas Frederick, Lowdham, Notts.
 Roberts, Ellis, London.
 Senior, Arthur M., Hove, Sussex.
 Sexton, Eric Hyde Lord, M.A., Cambridge, Mass., U.S.A.
 Suter, Albert Frederick, Kingswood, Surrey.
 Symonds, Robert Wemyss, London.
 Tagore, Maharaj Kumar Probirendra Mohun, Calcutta, India.
 Walker, Matthew Biggar, Wolverhampton.
 Watson, Geoffrey, Crowborough, Sussex.
 Weston, Louis, Ph.D., London.
 Wigley, Albert Ernest, New Orleans, La., U.S.A.
 Yeend-King, Miss Lilian, West Wittering, Sussex.

Other formal and financial business was transacted.

DR. MANN JUVENILE LECTURES.

Under the Dr. Mann Trust, PROFESSOR ARTHUR SMITHELLS, C.M.G., D.Sc., F.R.S., Director, Salter's Institute of Industrial Chemistry, will give two lectures for children on "Flame," at 3 p.m. on Wednesday, January 4th and 11th. The lectures will be fully illustrated by experiments.

Special tickets are required for these lectures. A sufficient number to fill the room will be issued to Fellows in the order in which applications are received, and the issue will then be discontinued. Subject to these conditions, each Fellow is entitled to one ticket admitting two children and one adult. Fellows who desire tickets are requested to apply to the Secretary at once.

Tea will be served in the library after each lecture.

SEVENTH ORDINARY MEETING.

WEDNESDAY, DECEMBER 14th, 1927. SIR FRANK BAINES, C.V.O., C.B.E., in the Chair.

A paper entitled "The Evolution of Modern Road Surfaces" was read by MAJOR G. H. CLEMENTS, M.C., M.Inst.C.E. The paper and discussion will be published in the *Journal* dated January 20th.

 PROCEEDINGS OF THE SOCIETY.

DOMINIONS AND COLONIES SECTION.

MONDAY, NOVEMBER 28TH, 1927.

THE RT. HON. SIR MAURICE DE BUNSEN, BT., G.C.M.G., G.C.V.O., in the Chair.

THE CHAIRMAN said he felt it a very great privilege to be presiding that evening by the kind invitation of the Royal Society of Arts, and the more so because for a good many years of his diplomatic career he had been in touch with what was going on in Spain and in Morocco, and had had frequent opportunities of meeting. His Excellency the Spanish Ambassador, who was lecturing that evening. It brought back to his recollection the fact that one day, when sitting in a room at the British Embassy in Madrid, a year or two before the War, he was rung up by the Spanish Foreign Minister, who said: "I have something to tell you, and I am anxious that you should have it before anybody else, and that is that we are about to fill up our vacant post at the Spanish Embassy in London, and we are sending you the best we have—we are sending you Señor Merry del Val." His Excellency had been with us for a number of years, and there were few more familiar figures in London or throughout the country than the Spanish Ambassador and Madame Merry del Val. He was a *persona gratissima*, and deserved to be so. He well remembered in those war years the many little difficulties His Excellency smoothed over, and how he kept up close touch between the two countries throughout the war. What he had most at heart perhaps was the continued friendship between the two countries, and he had done a great deal to promote that result. He was a great patriot. There was no period during that difficult four or five years of the Riff War when he lost confidence, and he did not believe His Excellency ever did lose confidence, although they were most terrible times. The difficulties encountered by all civilised nations when they sought to spread their civilisation among people of another stage of civilisation led, in almost all cases, to occasional disaster. It led to disaster in the case of the Riff War, a disaster similar to that which this country suffered in the Khyber Pass and at Isandwala, and the Italians had a similar disaster in 1896 near the Red Sea. Still, he did not believe His Excellency ever doubted that in the end Spain would get the upper hand and would inaugurate a peaceful era of co-operation, carrying on her protectorate in the Northern parts of Africa, in touch with all the native tribes, not seeking directly to administer those living in the wild mountains, but allowing them a certain

amount of autonomy. In that way a new era of peace was being inaugurated by the friendly Spanish nation, about whose doings something was to be said that evening from the most authoritative source possible. He felt everyone would welcome the opportunity of seeing a film which would be a proof of the extent to which peace had been really restored in a disturbed region. The film would show what always happened in moments of crisis and difficulties, the King and Queen of Spain going themselves to the seat of the trouble and receiving the good wishes and congratulations of the tribes. It must have been a great and stirring moment.

The following paper was then read:—

THE VISIT OF THEIR MAJESTIES THE KING AND QUEEN OF SPAIN TO THE SPANISH ZONE OF MOROCCO.

By HIS EXCELLENCY THE SPANISH AMBASSADOR, THE MARQUIS DE MERLY
DEL VAL, G.C.V.O., LL.D.

On 31st May last Don Tomas Baldasano, London Correspondent of "La Epoca," gave an interesting lecture in this very Hall on the subject of "Spain's work in Morocco." In my turn I am now kindly authorised by the Royal Society of Arts to show and explain a film descriptive of the recent visit of Their Majesties The King and Queen of Spain, whom I have the great honour to represent in this country, to both the regions of the Spanish Zone of Morocco, which until a year ago were the scenes of hard fighting begun in May, 1909, when the Spanish troops first marched out of Melilla to impose the Sultan of Morocco's effective authority in his province of the Riff. These two districts are known respectively by the name of Djebala and the Riff, and both, particularly the latter, are famed for the mountainous character of the territory and the fighting qualities of the inhabitants.

Sr. Baldasano in his lecture made us acquainted with a great part of what Spain has been doing for the Moors ever since 1909, for it is to her honour that, in spite of not figuring among the wealthiest nations of the world, she has from the first made her engineers, her doctors, her schoolmasters and her agricultural teachers follow in the wake of her armies. Thus it is that more than 1000 miles of roads have been built within her zone, and of these 600 since the Spanish troops landed in September, 1925, just outside Alhucemas Bay, some thirty thousand natives being employed in this task under the supervision of Spanish foremen, inspectors and engineers. Telegraph and telephone lines have been established across the Zone and in every large town, four fine ports have been built or are far advanced towards completion, and railway lines were laid down as far back as 1910, being the first to be opened in Morocco. Waterworks on the roads, and in the vicinity of towns and villages have been built, as also native hospitals, dispensaries and schools. Agriculture is taught to the natives and farming implements distributed among

them, ploughs being frequently loaned, even before the establishment of peace, to the unsubdued tribes. All this and more was told us by Sr. Baldasano, who showed on the screen examples of all this work in proof of his assertions.

I was particularly gratified by the spontaneous corroborative testimony offered by Mr. Henry Leach, who had just returned from the Riff, and Lieut.-Col. E. A. Ewart.

This afternoon I am about to show you the result of Spain's military and civilian work in Morocco as exemplified by the recent visit of Their Majesties The King and Queen of Spain.

The whole of the Spanish Zone is now completely and permanently pacified. More than 45,000 rifles, 140 pieces of artillery, numerous machine guns and ammunition have been surrendered, and this, added to the construction of a network of roads over the whole of the Riff, ensures the future against any possible rising which can never attain general or serious proportions. The same can be said of the Djebala country, where resistance was prolonged for a good many months after it had ceased among the more warlike, but also more intelligent, Riff tribes after the surrender of Abd-el-Krim. This event was the culmination of the campaign carried out, thanks to a happy and cordial understanding, by the Spanish and French troops conjointly from May, 1925, until the summer of 1926. The initial and decisive operation was the landing of the Spanish troops at Alhucemas in September, 1925, and the taking of Azdir, till then the stronghold of Abd-el-Krim and his fighting men. This success was completed by three months stiff fighting on the part of the Spanish troops until they joined hands with their French comrades on the border of the French Zone, and a year afterwards by the submission of the whole of the Djebala country and the end of the rather futile Ketama rising in the early summer of 1927.

The achievement of a task which had cost so much blood and treasure seemed a fitting moment for the visit of the Sovereign of Spain and his Consort to the territory now completely pacified. The situation happily existing in the Kingdom itself since the advent to power of the present Government in 1923 appeared to make the occasion doubly auspicious.

Their Majesties' visit was carried out under the most brilliant conditions and was favoured by the best of weather on sea and land, so that the excursion may be considered an unqualified success. The enthusiasm with which the King and Queen of Spain were awaited and greeted surpasses description, scenes of delirious joy being witnessed at different points during their Majesties' journey. The native inhabitants cordially took part in this reception, flocking into the towns from the country round, from the most distant points of the Zone, while the several tribes paid their homage to King Alfonso XIII and Queen Victoria Eugenia, not only by their presence and demonstrations of

welcome, but also by the offering of valuable presents. The very men who eighteen months ago were stubbornly fighting the Spanish Forces in the Riff came in great numbers. There is nothing strange in this change of attitude to those acquainted with Oriental mentality. In fact, since the submission of the Riff thousands of Moors from that once most hostile part of the territory have fought against their brothers of the Djebala mountains under the flag of Spain. But their presence was in reality a proof of the complete pacification of the Zone, confirmed by the personal experience of people well known in this country who are perhaps among us here this afternoon. Last April the well-known English journalist and writer, Mr. Henry Leach, safely traversed the whole of the Riff country in a motor car without an escort, and later came to bear witness to this fact in this very hall where we are now assembled. He is not, however, the only one to have made this pleasant experience. It is but a week ago since a remarkable account was published by *The Times* describing a similar excursion, which extended from Tetuan to Melilla through the Ketama country and the rest of the Riff, not only without the least mishap, but in the midst of friendly and helpful manifestations on the part of the native inhabitants. Lastly, only two months have passed since Her Excellency the Duchess de la Victoria, the heroic director and manager of the Spanish Red Cross Hospitals in Morocco, was able to motor through the Djebala country without a weapon of any kind in her car, or a male escort beyond the driver, who went unarmed. Another pleasing feature of their Majesties' reception was the share taken in it by hundreds of the inhabitants of Tangier, an essentially Spanish town, who seized the opportunity to show their loyalty and love for Spain and her Sovereign. It is a remarkable and well-known fact to all who have lived in Morocco that Spain is particularly popular among the Jewish community, and the latter did not fail on this occasion to prove it in every way. True it is that the Spaniard gets on individually very well with the natives of every race, as in the neighbouring country of Algeria. In spite of all that is published to the contrary, the two races, Spaniard and Moor, understand each other perfectly and live together in peace as once in the Peninsula itself.

In this connection I should like to call your attention to an incident which you will presently witness on the screen. An aged and burly Moor on appearing before the King and Queen of Spain is so dazed that in his anxiety to have a good view of Their Majesties he forgets to make his obeisance in proper local fashion, which consists in kissing the ground, a common form of salutation to Royalty in the East, as everyone knows who has seen a durbar in India or travelled in other countries of the Orient. The Master of Ceremonies, who, mark you, is a Moorish Mechouari or Court Official, reminds him rather roughly, *more mauretanico*, of his duty. Certain so-called friends, even among those who owe a debt of hospitality to Spain in Morocco, have attempted to interpret this insignificant event as a case of ill-treatment of the Moors by Spain. I need hardly say that there was nothing of the kind during Their Majesties'

visit, and as a matter of fact the individual in question so apparently lost his head that when he had finished his act of homage he remained staring at the King and Queen instead of retiring, until bundled about his business. There is a certain danger in these acts of homage on the part of the natives, for they frequently attempt to turn them into an appeal for interference on the part of the Authority whom they have come formally to salute, much as was the custom in those Biblical days so like the present state of Morocco. It is quite possible that the old man in question wanted to request the King of Spain to obtain the return of some sheep or a piece of land he considered had been wrongly taken possession of by some neighbour, and tactlessly chose the moment of the ceremony to make known his aspiration. Hence his reluctance first to make his bow and then to depart.

I will now explain the contents of the film as it passes before your eyes, but before doing so I should like to thank our Chairman of this afternoon, Sir Maurice de Bunsen, for so kindly introducing me to you and supporting me in your presence. His is a name still to conjure with in Spain after the many years which have elapsed since he so ably discharged the functions of H.B.M.'s Ambassador in Madrid, to the satisfaction of your Government and of all Spaniards, a notable example of the work a diplomat can do to make his people known, respected and loved in another land.

As we look upon the pictures now to be unrolled before our gaze I would have you remember that Their Majesties the King and Queen of Spain started from Algeçiras for Ceuta in the Djebala country on 5th October last, and left the Riff on the 8th of the same month, landing at Malaga the next day.

The film was then shown and explained by the Ambassador.

DISCUSSION.

THE CHAIRMAN said the subject of the lecture and the film was most interesting to everyone, and certainly interested him very much indeed. He would not begin without thanking the Ambassador very heartily for the very kind things he had said about himself; it was, indeed, a pleasure to hear him say that his (the speaker's) own personality was still remembered in Spain, where he had spent many happy years. He was very fond of the country and felt at home, whenever he visited it, in almost any part of Spain. The subject of the lecture was of the deepest interest, and the film was indeed a wonderful record of the beginning of the era of peace after five years of the terrible warfare in which Spain had been engaged, and out of which, by the skill of her Government, she had emerged with great honour to herself and to her brave troops. He did not know whether there were many present who knew the Spanish soldier, who was a very fine soldier indeed; he was not spoilt with too many luxuries and was able to march all day on a handful of beans, and was a splendid fellow to command. The Spanish soldier had a very hard time in Morocco, and everyone wished Spain joy at the successful accomplishment of so great a task. The question was: Was England interested in Morocco? and his answer would be that we were very deeply and profoundly interested. From

the very beginning of recent events in Morocco, up to the time when Spain undertook the task of extending her protectorate over Northern Morocco it had not ceased to be a matter of the deepest importance to this country that Spain should emerge successfully from the trials of the long campaign. It was impossible to go through the whole history in a short time. The essential thing was that the Entente with France in 1904 laid the foundation for an understanding between France and England that Great Britain should go ahead in Egypt undisturbed by French rivalry, and that France should go ahead in Morocco undisturbed by British rivalry, and there was an important condition attached to that—a condition which never ceased to be brought before the negotiators of the Entente Treaty with France—namely, that Spain was in reality a third party to the Treaty and that nothing could be satisfactorily settled unless it met with the approval and support of Spain. That was a point of view which in 1903, when the Entente negotiations began, was constantly kept in the forefront by Lord Lansdowne when he negotiated with M. Cambon, the French Ambassador in London, and M. Delcassé, the French Minister for Foreign Affairs. The Treaty was signed in April, 1904, and he had with him a paper on which he had jotted down a record of what Lord Lansdowne said, namely, that before the country went any further it was necessary to make sure that we were carrying Spain with us, that her long interest along the coast was receiving full recognition, and in fact he demanded—and there was no opposition from France, who willingly concurred—that if Morocco broke up Spain should have the control of the coastline. It was indeed proposed, by the way, that the coastline should be from the Algerian frontier to Mazagan, but in the end a point nearer the north was chosen for the termination of the coastline—the mouth of the River Sebu. It was a long coast line which was not to be fortified, and the conditions were laid down in a Treaty. The matter was repeatedly brought before the French Government, with the result that after the Entente was signed between England and France in the autumn of 1904 there was an important Treaty between Spain and France, in which the partition of the country in the event of Morocco breaking up was agreed upon, and the delimitation of the Spanish sphere and the French sphere of influence was duly arranged. That was communicated to the British Government, which agreed, and then began a new order of things in Morocco. Morocco very soon after that did break up and France entered on her sphere in the South, and Spain on her sphere in the North. Of course that led to a good deal of friction between some of the powers. Germany was very much dissatisfied at being left out, and in the end a Treaty was arranged with France by which a considerable slice of the French Congo was given up to her in exchange for her giving up claims in Morocco. Then came the Treaty between France and Morocco, which was concluded at the beginning of 1912 at Fez, which stipulated exactly what the relations between the Sultan and France were to be, and which required that France should come to terms with Spain as to the Spanish sphere in the North. Then came the important Treaty between France and Spain, which was concluded in November, 1912, and that really laid down the conditions which existed when the Great War broke out, Spain and France being fully established in their respective spheres. That Treaty was one which interested him personally, because the two Governments who were about to enter upon the Treaty did him the honour to ask him to be present at the negotiations, although England was not a party. It was recognised that England had very large interests in that part of the world, especially in connection with the freedom of the Straits leading into the Mediterranean. He had the advantage of being present throughout the whole of the negotiations, which resulted in a Treaty favourable to all the parties concerned. The Great War broke

out soon after that and nothing particular happened during the War in Morocco, but, curiously enough, soon after the conclusion of the War a movement broke out in the Islamic world, extending throughout large parts of Asia and Africa, which showed that the people occupying those countries were not any longer content to go on under the immediate domination of foreign countries. There was a kind of loss of prestige on the part of Europe in the eyes of the Asiatic and African peoples as the result of the War, and they had the idea of self-determination, although probably they did not know what it meant. Great changes took place throughout Africa and throughout large parts of Asia. He need only specify that Afghanistan was now completely independent, Persia had thrown off the quasi-protection of Russia in the North and Great Britain in the South and was a completely independent country; Turkey had asserted her complete independence, and England had surrendered to Egypt the protectorate and given Egypt independence, subject to a few restrictions arising out of the necessity of keeping up communications with India. Also, in Syria France had had great difficulties in meeting the demands of the natives. In Libya Italy had also had great difficulties. Tunis asked for an autonomous Government and got it to a certain extent. In Algeria the French rule had been long established, and Algeria had become very much like a portion of France. He did not know that any particular movement took place there, but the general movement spread also to Morocco, and that was fundamentally the reason why the great revolt of Abd-el-Krim took place. It was in sympathy with similar movements which were taking place throughout great parts of Africa and Asia. It was indeed a serious rising with deep meaning underlying it, namely, that countries of a different civilisation demanded to be governed according to their own notions, and were prepared to run great risks to obtain that privilege. He believed there was something in that movement and that most countries had agreed to accept and meet it to a large extent. This country had certainly done so, and he believed from what he had heard that it was the intention of the Spanish Government, as it certainly was of the British Government in their own dependencies, to rule largely through the indigenous native tribes, not interfering too much with their habits and customs, but allowing them considerable autonomy in their mountains subject to the protectorate and to the sovereignty of Spain. That he believed to be the policy of the Spanish Government. The film had shown the happy faces of the Chiefs, who seemed to be quite contented with what was in store for them, and he thought there must be a large measure of autonomy under the beneficent protectorate of Spain. Anyhow, Spain might be assured that this country entirely approve of her being the protecting power in Northern Morocco. From the very first that was a point strongly insisted upon by Lord Lansdowne in his negotiations with France. This country was anxious that Spanish wishes in that part of the world should be met and they were carried out with the full support, sympathy and co-operation of the British Government at the time, and he believed that policy remained unaltered in that respect, namely, that this country was glad to feel that Spain occupied such an important line of territory. It was felt that the peace of the world, and especially of that part of Europe and Africa, was promoted by the fact of Spain's presence there, and the Ambassador need have no doubt about that being the truth. This country viewed with sympathy and sorrow the losses that had been sustained by the Spanish Army, and had great admiration and rejoiced at the final success which had been won by the bravery of the Spanish troops.

MAJOR SIR HUMPHREY LEGGETT, R.E., D.S.O. (Chairman, Dominions and Colonies Section), said he had a very pleasant duty, on behalf of the Royal Society

of Arts, to propose a vote of thanks to the lecturer for giving the Society the great privilege they had enjoyed in listening to the lecture and seeing the film, and also he wished to thank the Chairman for giving some of the inner history of a very fascinating country. The meeting was composed not only of members of the Royal Society of Arts, but there were also present a number of members of the African Society of Great Britain, and he was asked by the President of that Society, Lord Buxton, to say how much he regretted that he was unfortunately prevented by a previous engagement from being present, as he would have wished in the name of that Society to pay a tribute to the great and successful efforts of Spain in her North African Protectorate. The Chairman had asked whether Morocco interested the people of this country, but it would be noticed that the lecture room of the Society had been too small that afternoon to hold the number of people who wished to hear the Spanish Ambassador, and that, he thought, was a small evidence of the interest taken in the subject. The man in the street, as well as those responsible for British diplomacy, was becoming more and more interested in the habits, customs and history and the future of African Dependencies, and now, with the very last instalment of Spanish Morocco, those countries were open to all the world to visit. In the name of all who were present, and of the Royal Society of Arts, he proposed a very cordial vote of thanks to Sir Maurice de Bunsen for having presided that afternoon, and to His Excellency the Spanish Ambassador, the Marquis de Merry del Val, for giving so interesting an exhibition, and he was sure everyone would wish to offer to Their Majesties and the Spanish people their very cordial congratulations on the successful efforts Spain had made in North Africa.

The vote of thanks was carried unanimously.

H.E. THE SPANISH AMBASSADOR said he wished to say a brief word of appreciation of the kind expressions that had been used about him. He was grateful to everyone for the way they had received him that afternoon, and his gratitude was especially directed towards Sir Maurice de Bunsen's allusion to the Spanish Army, of which all Spaniards felt so proud, and he wished to thank the Chairman in the name of that Army for the words of praise and appreciation he had given to a body of men who had inherited the fine old traditions which could justly be said to come down from the time of the Romans to whose armies Spain had offered so glorious a resistance. The film was taken by members of the Spanish Army on instructions from the Minister of War, and was therefore a military film, and showed to what extent the Spanish Army was organised for every sort of work. It was very largely owing to them that Spain's work of civilisation was carried out in Morocco. All the roads recently built in the Riff had been built under the direction of Spanish military engineers, and wherever they went their first work was to enclose the native springs and render them fit for human use. They had with them doctors who went out amongst the troops, even amongst the unsubmitted tribes, and tried to improve and help the country. Sir Maurice de Bunsen had expressed the hope that Spain intended to govern the Moors in the same way as was done in the French zone, through their own native authorities. That had been always done in the Spanish zone. No measure was applied to the natives and no decree ever published except in the Sultan's name or of the Government at Tetuan and countersigned by the Sultan's representative, H.H. Moulay el M. hedi, and his Minister. In the outlying districts each tribe was governed by its own hereditary chief under the advice of a local Spanish authority, and everywhere an endeavour was made to govern the Moors through their own authorities. Their religion and customs were respected down to the most minute detail. In all cases where any mosque had been destroyed by gunfire during an engagement it had been built up again at

the expense of the Spanish Government. There was no feeling on that score between Moors and Spaniards, he was happy to say. He had also been very pleased to listen to Sir Maurice's very able exposition of the origin of the present political situation which authorised the presence of Spain in Morocco, and he was especially glad to take the occasion to proclaim publicly what his Government—not only the present Government, but all the Governments which he had had the honour to represent in Great Britain for the last fifteen years, including the four years of stress and difficulty between 1914 and 1918—had charged him again and again to say, that the fundamental policy of Spain rested upon her deep and unalterable friendship with Great Britain and France. Spain maintained friendly relations with all powers, but that was the foundation of her foreign policy and was, moreover, the wish not only of her King and her Government, but of all her people. In conclusion, he thanked all those present for their great kindness to him that evening, although he took it as not addressed to himself but as addressed to his King, his Government and his Country.

The meeting then terminated.

NOTES ON BOOKS.

THE ATOMIC SCIENCE: RX THE LIFE ATOM. By Calvin Samuel Page. Chicago: Science Publishing Co. \$5.00.

To the above particulars it is only fair to add that the publishers undertake to refund the price to dissatisfied purchasers. The general character of the book may be sufficiently apprehended from a quotation from the wrapper: "This book is new facts not found in any other books or encyclopedias, and more new discoveries than ever before given in a single book;" together with one from the body of the work: "*Light is the Atmosphere!* The blue sky and the white hemisphere of illumination it enfolds are the objective Atmosphere! . . . The feeble light of the prison cell is the air! The mysterious messengers of Radio are the air! . . . They are absolutely the thing, air, and the material rx from the material molecules is the light that reveals them;" and finally from the last sentence of the book: "Rx is the only possible explanation of the inconceivable velocity of light, and in this particular meets the physical and spiritual declaration of Christ, I am the Light of the world."

Briefly, Mr. Page believes himself to have "discovered" a new kind of matter Rx atoms, which are without weight and which repel one another, but to which all other atoms tend to adhere; and upon this idea has attempted to build a new theory of the universe. There is nothing particularly repugnant to common sense in the concept as thus outlined; nor, if it were supported by trustworthy experimental evidence, and were shown by reasoned argument to be capable of reconciliation with the existing general body of recorded observations, would the scientific mind feel impelled to reject this theory on the ground of inherent incredibility.

Unfortunately, the reasoned argument is wholly lacking: in substance, the book is found to consist of a collection of unsupported assertions pretty much of the type just quoted, and frequently so illiterately expressed as to make it a weariness and a misery to read a page from beginning to end. As for experimental observation, the only adventure in this kind is the discovery, by means of apparatus constructed by the author, "wholly of brass," that the accepted law of reflexion of light is

inaccurate by amounts up to no less than 2° of angle. It is to be hoped that Mr. Page will make no attempt to pay this country the honour of a visit: with ships' sextants harbouring this degree of unsuspected error, there is no saying what landfall he might not make.

What is less humorous is the fact that he seems to have convinced a number of American newspapers of his credibility and importance. Those who have studied Mr. Mencken's annual collections of *Americana* will not be easily shocked by quotations from the American press; but it is a little disconcerting to find the *Boston Journal of Education* remarking, apparently without irony, that Mr. Page's discoveries, if valid, will "place him above Newton and every other contributor to the theories of science."

The illustrious mathematician De Morgan gave deep study to the psychological problem presented by the paradoxist and his dupes, and made an unrivalled collection of paradoxical literature. It would be cruel to quote here his dispassionate analysis of the mentality of this type of author, but it is interesting to note that he did not succeed in formulating any really satisfactory intellectual criterion whereby an impartial "outsider" would be enabled to distinguish such persons from critical investigators. The reason is not far to seek: silliness is a spiritual rather than an intellectual condition.

THE HIGHER COAL-TAR HYDROCARBONS. By Arthur Ernest Everest, D.Sc., Ph.D., F.I.C. London: Longmans, Green & Co., Ltd. 18s. net.

In this monograph, which will attract the attention of every organic chemist, the author has given an admirable account of the work which has been done up to the present time on the more complex condensed nuclei. By the excellent plan of omitting all reference to naphthalene and anthracene derivatives, which have been dealt with satisfactorily by other writers, sufficient space has been made available for the full treatment of the still larger molecules; and chemists whose main interests have lain in other directions may perhaps be surprised to see how large those molecules can be.

The substance Cyananthrene O, for example, contains no fewer than eleven linked hexagonal "rings" in its molecule, and its constitutional formula covers with reticulations a respectable fraction of a page. It is no uncommon thing, moreover, for a ring to be so hemmed in that its six carbon atoms are all directly attached to other cyclic carbons; and the author refers to the interesting speculation that possibly this method of linkage may be that which exists in the structure of carbon itself.

These complex substances are for the most part found as coal-tar products, though some have risen synthetically. They have so far found practical application mainly in pharmacy and in the dyeing industry; but Dr. Everest remarks, with respect to some of the higher examples, that we are as yet on practically untrodden ground, and recommends this line of investigation to those who complain that virgin fields are becoming scarce.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

THURSDAY, DECEMBER 29. Colonial Institute, at the Hotel Victoria, Northumberland Avenue, W.C. 3 p.m. Mrs. Charlotte Mansfield, "My Tramp through Africa." (Juvenile Lecture.)
Royal Institution, 21, Albemarle Street, W. 3 p.m. Professor E. N. da C. Andrade, "Engines (Lecture I) The Rules which all Engines must obey."

FRIDAY, DECEMBER 30. Architects, Royal Institute of British, 9, Conduit Street, W. 4 p.m. Mr. C. H. B. Quennell, "Every day Things in Roman Britain." (Juvenile Lecture.)

British National Opera Company, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 3 p.m. General Meeting.

SATURDAY, DECEMBER 31. Royal Institution, 21, Albemarle Street, W. 3 p.m. Prof. E. N. da C. Andrade, "Engines (Lecture II)—Learning about Steam."

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FRIDAY, DECEMBER 30th, 1927.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

DR. MANN JUVENILE LECTURES.

Under the Dr. Mann Trust, PROFESSOR ARTHUR SMITHELLS, C.M.G., D.Sc., F.R.S., Director, Salter's Institute of Industrial Chemistry, will give two lectures for children on "Flame," at 3 p.m. on Wednesday, January 4th and 11th. The lectures will be fully illustrated by experiments.

Special tickets are required for these lectures. A sufficient number to fill the room will be issued to Fellows in the order in which applications are received, and the issue will then be discontinued. Subject to these conditions, each Fellow is entitled to one ticket admitting two children and one adult. A few tickets are still available and Fellows who desire tickets are requested to apply to the Secretary at once.

Tea will be served in the library after each lecture.

PROCEEDINGS OF THE SOCIETY.

FIFTH ORDINARY MEETING.

WEDNESDAY, NOVEMBER 30TH, 1927.

H.E. THE FRENCH AMBASSADOR, M. DE FLEURIAU, Commandeur Légion d'Honneur, G.C.V.O., in the Chair.

THE CHAIRMAN said the Royal Society of Arts had conferred upon him the great honour of asking him to preside at the present lecture concerning a very great scientist. He had had the honour of meeting M. Berthelot a little more than 30 years ago, when for a short time M. Berthelot had left his ordinary work of science to enter into politics, and had become the French Minister of Foreign Affairs. The picture which M. Berthelot had then presented to his mind had been that of a very tall man, appearing to be not very physically strong, with a very broad forehead,

and with eyes which appeared to be looking into himself more than to be looking outside. M. Berthelot had been devoted to science and to his family; he had been a very devoted husband and lived in complete and happy union with his wife. He had left to all his children a very strong feeling of family ties. All these things were perhaps very far removed from the actual subject of the lecture, but he had thought that perhaps the audience would be interested to see M. Berthelot as he himself had seen him.

The following paper was then read :—

MARCELLIN BERTHELOT AND SYNTHETIC CHEMISTRY.

A STUDY AND AN INTERPRETATION.

1827 (OCT. 25) — 1907 (March 18).

By HENRY EDWARD ARMSTRONG, Ph.D., LL.D., D.Sc., F.R.S.,

Emeritus Professor of Chemistry at the City and Guilds College,
South Kensington.

“ Il faut se représenter la science comme un édifice séculaire qui ne pourra s'élever que par l'accumulation de masses énormes. Une vie entière de laborieux travaux ne sera qu' une pierre obscure et sans nom dans ses constructions gigantesques. . . La gloire des premiers explorateurs est d'être dépassés et de donner à leurs successeurs les moyens par lesquels ceux-ci les dépasseront.”

(E. Renan. L'Avenir de la science.)

“ Les erreurs de ceux qui, dans les sciences, ont accompli une vaillante carrière, n'ont que l'intérêt philosophique qui s'attache à la connaissance de notre humaine faiblesse.” (Pasteur.)

The genius of Berthelot is to be acclaimed as that of a worker in many fields, in all of which he was a pioneer explorer, the first to formulate chemistry as a creative science and the first to use electricity constructively in its service. Largely upon the simple foundations which he laid, chemists have worked with such skill and success that they may now claim to be gifted almost with the power of life itself. He it was who advisedly first broke down the long fancied barrier between the mineral and the organic worlds and put the intuitive hope into our minds, that there were no rational problems concerning the materials of our earth or the changes they undergo which we need fear to attack. Full honour was paid to him at the time of his *Cinquantenaire scientifique* in 1901. The recent celebration, in Paris, of the centenary of his birth, whilst serving again as an opportunity of calling public attention to the value of his services, was of too political and general a character either to promote intimate understanding of his mental gifts or to display the precise manner in which these became developed and applied. Subject to unusual educative influences, a cryptic character from his youth onwards, the attempt to dissect



FIG. 1.—Berthelot when assistant at the Collège de France.



FIG. 2.—Berthelot in his laboratory at the Collège de France. The likeness to the profile on the very beautiful medal by Chaplain, presented to him on his *Cinquantième scientifique*, is noteworthy.

out and interpret the psychic complexities underlying his manifold activities is a task of utmost difficulty. He long hesitated what he should be : it is not easy to show what he became, still less quite to understand why.

Although so recent, his work is little considered by students to-day, as these are forced to gather their knowledge by attendance at formal lectures, fashioned to soulless examination programmes, as well as from brief and often ill-digested statements, uncritically and superficially thrown together in text-books and abstracts. They have neither inclination nor time to read the original literature nor can they ponder the historical development of our science, the styles of individual workers, in order to shape their own style. We seem, in fact, to be fast losing the conception of culture in scientific education. Consequently, we care little whether or no we fathom the minds of the men who preceded us and but work in blinkers.

Born October 25th, 1827, Berthelot was the son of a medical man practising in a poor quarter of Paris. His first schooling was at a small local school, where he developed a faculty for mental arithmetic which was of service to him later on in his thermal work. He then passed into the Collège Henri IV, where his remarkable intellectual superiority soon became apparent. He was there highly distinguished as a classical scholar, devoting himself to literary, historical and philosophical study. He excelled in Latin verse. In 1846, when eighteen years old, he gained the *Prix d'honneur de philosophie* in the open competition between all the French lycées. As his biographer Schützenberger points out, the words he uses of Lavoisier may equally well be applied to himself :

“ Il obtint le grand prix de discours français en rhétorique, au concours general : c'est-à-dire, qu'il entra dans la vie avec la culture classique, qui ne fait certes pas les grands hommes mais qui leur assure cette forte éducation de l'esprit, cette pratique de travail et cette habitude d'écrire, si nécessaires à la poursuite méthodique de leurs travaux comme à la propagation de leur idées.”

He appears to have been unable to make a clear choice of a career at this time and even long afterwards. After gaining the degree of Bachelor of letters (Aug. 8, 1846), he continued to attend at the Collège Henri IV, taking the special course in Mathematics. He passed the examination for the Bachelor's degree in Mathematical Sciences, Aug. 12, 1848. During these two years, he was also browsing upon the lectures of various professors in the Collège de France. He seems to have had an insatiable desire for knowledge. In fact, he has told us, that having formed the plan in his mind that he would acquire an understanding of the principles of all the sciences, he had mapped out his course of study in hours and weeks, counting upon his great powers of work and the ease with which he could change his mind, almost instantaneously, from one subject to another. However, he soon came to recognise how futile it was to make any such attempt. Influenced, doubtless, by his father's wishes,

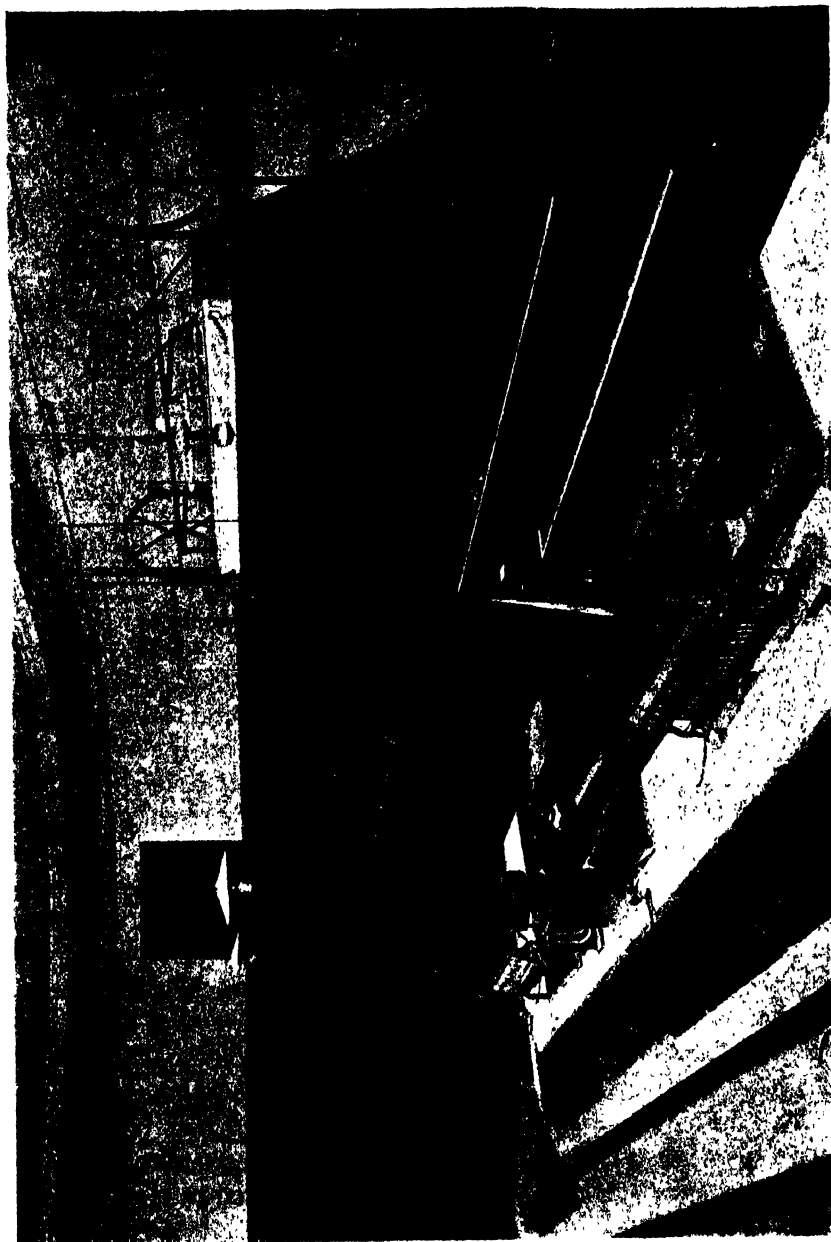


FIG. 3.—The Theatre at the Collège de France in which Berthelot lectured.

he began the formal study of medicine in November, 1848, and kept his name upon the register until the summer of 1850. This attempt to overcome the incarnate desire of his being was made to no purpose. The attractions of experimental science, chemistry especially, proving greater than those of medicine, towards the close of 1849, he began to work with Pelouze, who at this time left the Collège de France to establish a private laboratory. Berthelot's indecision may well have been, in part, due to his great craving for general knowledge, in part to the state of philosophic doubt into which, apparently, he was plunged during his early years. From ten years upwards his enjoyment of life seems to have been spoiled by an over-anxious, introspective disposition. He was ever tormented by 'doubts as to the future and its possibilities. An even greater influence, perhaps, was at work.

Probably, the most momentous event of his life occurred when, in November 1845, he first met the philosopher Ernest Renan, who was to become celebrated by his *Life of Jesus* and as historian of the origins of Christianity. Following the custom of the day, while still engaged in classical and literary study, in order to pursue his studies undisturbed, Berthelot had left home to live in the Pension Crouzet, a boarding-house dépendance of the Collège Henri IV. Renan had just withdrawn from a seminary and thereby severed the last link binding him to the Church. He was acting as tutor boarded without salary. Berthelot was 18, Renan was four years his senior. The meeting has been described by both parties—by Renan in his *Souvenir d'enfance et de jeunesse*; by Berthelot in the volume of *Correspondence avec Renan* (1847-1892), which he published after the death of the latter. They occupied adjoining rooms and practically lived together. They were fast friends from the moment they met and the bonds of their friendship became ever stronger as time went on. The story they have together told of their relationship and of their intellectual intercourse is altogether remarkable and without parallel.

Berthelot has laid bare his own temperament, in describing his relations with Renan; Renan has supplemented the account in describing him.

Renan had had less experience of life and was of a soft and serious nature. They differed fundamentally in their conceptions. Renan's leanings were aristocratic and towards the past—he had little sympathy with democracy and the tendencies of modern civilisation. He speaks of Berthelot's father as having been the first republican whom he had met. Berthelot was inclined to sympathise with the conceptions of collectivism then coming into vogue. Each undoubtedly exercised a great influence upon the intellectual development of the other. Gifted with universal curiosity, they discussed every possible problem in philosophy. Renan's "*L'Avenir de la Science*" is the unripe product of their conversations. He describes the incessant fermentation of ideas in their minds in the dedication to Berthelot of his *Dialogues philosophiques*.

"Plus d'une fois, en retrouvant dans ces pages certaines idées dont nous avions maintes fois causé ensemble, je me suis demandé si elles étaient de

vous ou de moi, tant nos pensées se sont depuis trente ans entrelacées, tant il m'est impossible, dans notre intime association intellectuelle, de distinguer ce qui est mien de ce qui est vôtre. C'est comme si l'on voulait partager les membres de l'enfant entre le père et la mère. Tantôt l'embryon de l'idée est de vous et le développement m'appartient ; tantôt le germe est venu de moi et c'est vous qui l'avez fécondé. Tout ce que j'ai pu dire de bon sur l'ensemble de l'univers, je veux qu'on le regarde comme vous appartenant d'un autre côté, je réclame ma part dans la fermentation de votre esprit philosophique ; je n'en aurai pas de meilleure."

Probably, the greater influence was exercised by Berthelot : at least, in later years, when Renan often visited him in his laboratory at the Collège de France and was witness of the great sacrifice of time, thought and effort involved in experimental inquiry. He was there led to appreciate the fundamental and laborious character of such work, through direct observation, in a way permitted to few literary men—who mostly have no conception either of its nature and disciplinary value or of its moral effect.

Berthelot's first visit to the Collège de France was made in 1846, together with Renan, who was following Eugène Bernouff's course in Sanscrit. He was thus led to take part with a few other select students in the animated debates on comparative religion they had with the professor, a man of great erudition, from which Renan was to gain much inspiration for his later work. Berthelot, it is clear, was more attracted by the scientific lecturers of the College. Among those with whom he was brought into intimate contact were Biot, Claude Bernard, Dumas, Pelouze and the physicist Regnault, the last then at the full height of his fame. Though narrow in his general outlook, Regnault set an example, by his enthusiasm and the rigid accuracy of his experimental work, which had the greatest possible influence upon the growing student and probably determined his final choice of a career. At the close of 1849 he entered the private laboratory which Pelouze then established. He seems, however, to have hesitated up to the last moment, probably because of Renan's continual efforts to secure him for literary and philosophical study. This is clear from a letter Renan wrote from Rome, Feb. 17, 1850, which Berthelot was to receive only a few days before his first scientific communication was read before the Academy of Sciences:

"Ce que vous me dites de votre état m'attriste beaucoup, cher ami . . .

Je pense que les peines intérieures dont vous parler tiennent surtout à l'objet spécial de vos études, qui n'est pas précisément ce qu'il vous faut. Vous savez que j'ai toujours regretté de ne pas vous voir prendre comme étude officielle les sciences morales, philosophiques ou littéraires comme on dit ; c'est à elles que vous demandez votre aliment intérieur. J'imagine que cette scission entre votre vie spirituelle intérieure et officielle dérange souvent votre système de vie et vous produit de ces dégôts. Peut-être aussi vous condamnez-vous à une trop grande abstinence de la jouissance

esthétique. Cette jouissance est aussi individuelle ; elle est même égoïste, ce que je ne pensais pas autrefois ; mais elle est noble, elle élève. Vous savez admirer le beau, mais vous ne le cherchez pas assez."

The final paragraph of the letter is noteworthy, as reflecting upon Berthelot's lack of æsthetic interests. I have not found any evidence that he had artistic interests or any particular love of nature. He soon became assistant to Pelouze but not for long. Early in 1850 he made his official entry into the ranks of science, by becoming assistant to the genial Balard, at the Collège de France. Balard was the discoverer of bromine but otherwise not a scientific man of distinction. He had been appointed successor to Pelouze, as the nominee of the ultra-conservatives, from whom, in fact, Berthelot had received his training, in opposition to Laurent, through the help of the school led by Dumas, to whom the Laurent-Gerhardt doctrines were anathema.

Berthelot remained nearly ten years the associate of Balard. He seems to have paid not too much attention to the students but did a vast amount of work himself, which greatly raised the reputation of the school, so that Balard became very proud of his assistant and appears to have helped him in every way possible. In 1854 Berthelot took the Doctor's degree in Physical Science, his thesis being his celebrated memoir on the compounds of glycerin. Ever seeking to extend his knowledge, he next studied Pharmacy and graduated as a Pharmacist, in the first class, in November, 1858. The thesis he submitted contained a description of two remarkable new sugars, the biose Trehalose and the triose Melezitose. His excursion into pharmacy was to have noteworthy consequences. Organic Chemistry, being but an annex of mineral chemistry, had been taught at the École Supérieure de Pharmacie by assistant professors, Caventou and Gauthier de Claubry. Alive to the growth of the subject and of its particular importance in pharmaceutical studies, when Gauthier de Claubry was appointed to the Chair of Toxicology, in 1859, the authorities of the school advocated the creation of a full chair. Their proposal was supported by Dumas, then Inspector General of Public Instruction. In due course, the chair was established. It was the first exclusively devoted to the teaching of organic chemistry. Berthelot was appointed the first professor by an Imperial decree of Dec. 2, 1859.

His reputation was now established. A piquant and discriminating picture of the man at this time is to be found in one of Madame Didier's Letters:

"I had given a large dinner party at which more than usual were present, among others a young savant, a friend of Michelet. I paid him the more attention and pressed my hospitality upon him the more, because of the retired life he leads and of his extreme reticence. I much enjoyed M. Berthelot's conversation. My regret is that I cannot follow him in the field of science ; he has made great discoveries in chemistry, and published two big volumes which are beyond me. . . There seems to be nothing that he does not know ; he has had a high literary education ; he only does not know

how to dress and look like other people. His mother is very devout, very catholic. She kept him under severe control. He was under this yoke until he was twenty years old. He is scarcely his own master now that he is thirty-two and is in no way emancipated, only he is a free-thinker."

The pictures preserved of him but serve to confirm this estimate of his serious character; only in later life is he seen to smile.

In May, 1861, Berthelot married Mlle. Sophie Niaudet, niece of Breguet. They had a family of four sons and two daughters.

After his appointment he continued to work in Balard's laboratory. The erection of a special laboratory at the École de Pharmacie was long delayed but it was eventually built and it was there that he synthesised acetylene.

The effect produced by the publication, in 1860, of the two volumes of his work: *Chimie organique fondée sur la synthèse* was so great, that it was felt that such an innovator ought to be in a position to exercise his activity in a laboratory in which he could give special instruction in the art of extending the science which he was doing so much to rejuvenate. The Minister of Public Instruction, Druy, was at that time anxious to increase the facilities at the disposal of scientific workers for the prosecution of their inquiries. Having had Berthelot under him at the Collège Henri IV, Druy was particularly well disposed towards his distinguished pupil, who had done nothing but increase his reputation since he had left his charge: he was prepared, therefore, to listen to the proposals of Berthelot's now numerous admirers, who were supported by seniors such as Dumas and Balard. By an order of Dec. 24, 1863, the Professor at the Collège de Pharmacie was charged also with the delivery of a course on Organic Chemistry at the Collège de France. As soon as Berthelot had delivered his first course, he published the lectures under the title "*Méthodes générales de synthèse en Chimie organique*," thus making clear the importance and value of the new teaching. As a consequence, by an order of Aug. 8, 1865, a separate chair of organic chemistry was now established and Berthelot was appointed full Professor in the Collège de France. He retained this post, resigning that at the College of Pharmacy, until the end of his life. In 1883, the means at his disposal were extended by the foundation at Meudon of a Station for Plant Chemistry, attached to his chair at the Collège de France.

A picture of the man, at a later age, is given in one of Zola's novels (1898), *Les Trois Villes, Paris*, in which he figures as Bertheroy, as follows:—

"Bertheroy vient donc toujours ici? . . . Ah! lui, je veux bien le voir, c'est un des meilleurs, un des plus larges esprits de ce temps. Il est resté mon maître.

"Ami autrefois de leur père, l'illustre chimiste Michel Froment, Bertheroy était aujourd'hui, à son tour, une des gloires les plus hautes de la France, à qui la chimie devait les extraordinaires progrès qui en ont fait la science mère, en train de renouveler la face du monde. Membre de l'Institut, comblé de charges et d'honneurs, il avait gardé pour Fierre une grande affection, il le visitait ainsi parfois avant le dîner, afin de se distraire, disait-il."

"Septuagénaire, il était grand, sec, avec des traits anguleux. La peau jaunie se collait comme un parchemin sur les os saillants des joues et des mâchoires. D'ailleurs, sans aucun prestige, il avait l'air d'un vieil herboriste. Mais le front était beau, large, uni, et sous les cheveux blancs ébouriffés luisaient encore des yeux de flamme."

His outlook and the opinion that was held of him in his latter years are probably well expressed in the following passage, in which Bertheroy comments upon a recent bomb outrage :—

"Ah ! mes amis, si vous saviez combien je trouve un tel acte plus inutile encore que criminel ! Je n'ai que mépris pour les agitations vaines de la politique, aussi bien la révolutionnaire que la conservatrice. Est-ce que la science ne suffit pas ? A quoi bon vouloir hâter les temps, lorsqu'un pas de la science avance plus l'humanité vers la cité de justice et de vérité, que cent ans de politique et de révolte sociale ? Allez, elle seule balaye les dogmes, emporte les dieux, fait de la lumière et du bonheur . . . C'est moi, le membre de l'Institut, renté, décoré, qui suis le seul révolutionnaire."

"Il se mit à rire, et Guillaume sentit l'ironie bonne enfant de ce rire. S'il admirait en lui le grand savant, il avait jusque-là souffert de le voir si bourgeoisement installé dans la vie, laissant venir à lui les situations et les honneurs, républicain sous la république, mais tout prêt à servir la science sous n'importe quel maître. Et voilà que, de cet opportuniste, de ce savant hiérarchisé, de ce travailleur qui acceptait de toutes les mains la richesse et la gloire, se dégageait un tranquille et terrible évolutionniste, comptant bien que sa besogne allait quand même ravager et renouveler le monde !"

Many will have visited the laboratories in which Berthelot worked at the Collège de France, at the time of the recent celebration, in Paris, of the centenary of his birth. They may have wondered at the simplicity of the small lecture room in which a select body of students was brought into intimate association with the Master. Fig. 3 is a reproduction of a photograph of the room as it now is, showing the very primitive character of the seating arrangements. The large mercury trough in which he was so fond of giving demonstrations with gases is to be seen close to the one end of the lecture table. Some may have thought that the laboratories were, to say the least, old-fashioned and cramped. They are so, in comparison with the modern palaces to which now-a-days we are accustomed. However, they still serve a good purpose, as there is space in them only for real students. Judging from the character of the remarkable work carried on by Berthelot's successor, M. Moureu, it is clear that, as now and ever shall be, the man counts before the means. Our modern scientific palaces are too often whited sepulchres serving to overcrowd the profession with the unfit.

It will be obvious that Berthelot's career was singularly unchequered. Until over thirty, he was assisted by his father, so that he was without pecuniary anxieties. Apparently, he never made any practical use of his discoveries.

We may now consider Berthelot's activity in the laboratory. Having chosen a scientific career, he at once came forward as an original worker—but in physics. His first paper, "*Sur un procédé simple et sans danger pour montrer la liquéfaction des gaz et celle de l'acide carbonique en particulier*," was read before the Academy of Sciences, May 27, 1850. In this he described a simple method of condensing a gas, in the fine stem of a large bulb filled with mercury, by means of the pressure developed by warming the mercury while cooling the end of the fine tube. He even attempted to liquefy air by this method.

Why such a subject, why a physical theme at all, if chemistry were the attraction which led him away from medicine? No reference is made anywhere to his having developed the use of his hands during his youth, yet from his insistence upon Regnault's great manipulative skill and the emphasis he lays upon the way in which Regnault had educated his son, a painter, to use his hands, we may be sure that Berthelot too had fingers. His whole career is but a proof that he was a born experimentalist: we may be sure that he turned from medicine to physical science to satisfy the desire within him to exercise an innate faculty. He began with physics, probably, because he was under the spell of Regnault's influence. How great this was is clear from the long address he delivered after his death, the most masterly and sympathetic of the many *éloges* he pronounced upon departed colleagues.

He tells us that when he first knew him, the fame of Gay-Lussac, of Dulong and of Faraday appeared to pale before that of Regnault. He describes him as a man of short figure, with a fine, characteristic head and pale blue eyes. He had given up his life to the pursuit of truth but this he envisaged as consisting in the determination of numerical constants. The genius of precision seemed to be incarnate in his person. He was, however, entirely hostile to theory and failed unfortunately to follow the development by Mayer, Joule and others of the mechanical theory of heat, so that he eventually found himself left behind. How far he had recovered himself will never be known. He had carried out a long series of experiments, to determine the relation between the heat consumed and the work done in gaseous explosions, when the war (1870) forced him to leave his laboratory at Sèvres. On his return, he found all his apparatus defaced, his thermometers cut up into lengths and the notebooks containing particulars of over six hundred experiments destroyed—one of the most barbaric acts of war ever exercised.

In his second communication to the Academy (June 24, 1850), *Sur quelques phénomènes de dilatation forcée des liquides*, Berthelot describes a curious experiment in which a strong capillary tube, closed at the one end and drawn out to a fine point at the other, filled with water at 28–30°, was cooled to 18°, so as to allow air to enter, then sealed. On heating gradually to 28° or slightly above, the air completely dissolved. On carefully cooling to 18°, the liquid continued to fill the tube, so that the density must be supposed to remain the same over the interval 28°–18°. The slightest vibration caused air to

separate from the liquid. What, we may ask, is the molecular state of the liquid in its state of "suspended animation"?

His aspirations were in no way satisfied by such exercise. Physics is not an experimental science, in the same sense that chemistry is; it is lacking particularly on the constructive side and the opportunities it offers for imaginative discovery. Berthelot was not then prepared to degenerate into the mere measuring machine, however accurate, that he saw Regnault was. Just as the sportsman has within him the primitive instinct of man to kill, to provide himself with food, so Berthelot had within him the chemist's desire to make something: possibly, had he never been brought under Regnault's influence, he would have remained a chemist throughout his life and have measured only incidentally. We have, however, also to consider the literary bias with which he was weighted—a bias which is against constructive work.

A year was to pass before he made his third communication to the Academy of Sciences: "*Action de la chaleur rouge sur l'alcool et sur l'acide acétique*" (Aug. 18, 1851). This was his first chemical essay. Why he selected such a subject for study is not clear. It is difficult to say what will have been in the mind of a young man of 23-24 in 1850-51, the more as Berthelot's mind was not that of an ordinary young chemist. He had disputed constantly with Renan and others. They had discussed all the great philosophical problems and were persuaded that the supernatural had no place in nature: he was unable to believe in the operation of a vital force in organic life distinct from that concerned in ordinary chemical operations. We can only suppose that he carried his habits of literary study into science and that, in the course of his reading, he had been struck on the one hand, by Lavoisier's contention that chemistry was an analytical science; on the other, by the very definite denial by Berzelius in particular, even by Gerhardt so recently as 1848, of the chemist's ability to make compounds such as were formed in animals and plants. He refers to all these authorities. It is clear that he set out upon his upward journey advisedly, bearing a banner inscribed with the device then entirely strange, *Organic synthesis*. He was to carry it forward and to cry *Excelsior!* with some effect. To-day, the mighty force of the falls at Niagara and elsewhere is being used to make great engines hum loudly to the *motif* he then first made heard but faintly. Unconsciously, perhaps, he was setting out to compose the great synthetic symphony which he eventually wrote. Why did he first choose *Alcohol* and *Acetic Acid* as *motifs*? They were to appear again and again throughout the work. I hope to show that to-day we *should* and to-morrow we shall more and more associate them with his name, in fact, speak of them in industry as the *Berthelot motifs*. We may hope that a Wagner will some day arise who will do justice to them in jubilant musical terms. Very complex compounds were known to be present in the tars formed by the destructive distillation of wood and coal. Could such be produced by heating simple vapours, for example, those of alcohol and acetic acid? This issue

seems to have been present, in the clearest possible shape, in Berthelot's mind. It is impossible to assign any other origin to the simple theme of this apparently slight opening movement of the synthetic symphony which was ultimately to immortalise his name. He was able to show that coal-tar products, such as benzene, naphthalene and even other more complex hydrocarbons, could all be built up from such simple beginnings, with the aid of heat. He thus laid the foundation of our modern interpretation of pyrogenic change.

During 1852 came a pause—the young composer, doubtless, saw the need of widening his horizon and of seeking inspiration for the further development of his genius. He discovered a counter-irritant to synthesis in turpentine—a well-known blistering agent, already an object of study favoured by French workers. The subject occupied him off and on during many years. In the course of his work he made the important discovery of a method of converting liquid turpentine into the isomeric, solid hydrocarbon camphene and by oxidising this he obtained camphor. In fact, he in part synthesised camphor. His method is in use to-day as a manufacturing process.

Thus refreshed, he took the emollient glycerin in hand and with its aid wrote the great second movement of his synthetic symphony. There is little doubt that he laid himself out to produce a work of importance, which would serve as his thesis for the Doctor's degree. The *motif* was derived from the classical work on fats of his great countryman, Chevreul; in fact, the movement was an inversion of Chevreul's work and the subject had already been indicated by Pelouze and Gélis, who had produced what was supposed to be the first artificial neutral fat, butyryn, by heating glycerin with butyric acid. Berthelot generalised at great length upon this theme and prepared a great variety of derivatives of glycerin, of three orders of complexity, by acting upon it with a large number of acids. In the course of the work, he synthesised Stearin and Palmitin, the chief constituents of ordinary hard fats. The full significance and great theoretical importance of the work was not recognised, until it was interpreted by Wurtz, in a sense Berthelot's rival and a member of the Gerhardt school. In fact, it was of far greater value to the chemical theory then coming to the fore, which was to confound the Dumas school, than as proof that natural materials could be produced by laboratory methods. Glycerin henceforth took rank as alcohol three times over, so to speak.

During 1854, Berthelot was occupied in amplifying the glycerin movement in his composition. Sugars also claimed his attention. 1855 was made for ever memorable by the publication of the great scherzo movement in the synthetic symphony—a trio based upon themes of surpassing simplicity, two of extreme loveliness, a succession of thrills. This time, the alcohol *motif* proper was announced with full blare of trumpets and by the entire orchestra. Alcohol, which had never before been made except with the aid of the yeast cell, by fermentation, was produced, from very simple materials, in the laboratory. It is not surprising that Berthelot soon achieved a great reputation—

it is difficult for us to-day to appreciate what the discovery meant, how complete a refutation it afforded of the view that had so long prevailed, that behind organic chemistry was a vital force which must ever defy man's feeble efforts.

Alcohol, said Berthelot, has always and only been made hitherto by means of fermentation—through the agency of living organisms, the yeast cell. It has been analysed by means of sulphuric acid and converted into the hydrocarbon gas, ethylene and water—let us put these together again. Berzelius had said, “all the king's horses and all the king's men couldn't put Humpty Dumpty together at all:” Berthelot showed that *he* could. He shook ethylene hard with sulphuric acid over a long period—behold, it dissolved and when he added water and distilled, alcohol passed over. However, the ethylene had been made from alcohol—so Berzelius was not quite confounded. Berthelot, therefore, separated ethylene from coal gas, as ethylene iodide, by passing crude gas into a solution containing iodine—and from this ethylene he prepared alcohol, identical, in every respect, with the natural article. If and when necessary, Berthelot's method can be used as a means of manufacturing alcohol—from coal: the method was developed during the late war but has not yet been made an economic process.

Just to give spice to his performance and vary the interest of the movement, Berthelot, in conjunction with De Lucca, then took the substance allylic iodide, made by the interaction of iodide of phosphorus and glycerin; by heating this iodide with potassic thiocyanate, they produced Mustard Oil—the substance whose warm and bathic virtues Baron de Beef is never tired of proclaiming to-day. It is indeed one of the most highly stimulative substances with which we are acquainted—able not so much to warm the cockles of the heart as to tickle the coats of the stomach to their highest digestive capacity.

To complete the movement, Berthelot now struck the very simple chord, carbonic oxide, CO, the much feared, highly poisonous product of imperfect combustion, known to everyone through the blue lambent flame which often appears at the top of the fire when it burns clear, poisonous because it has an astounding power of displacing the oxygen from our blood. Why did he seek to develop the music of the ant upon such a strange theme? we may ask. Simply because he reasoned, that carbonic oxide is related to formic acid in the same way that ethylene is to alcohol. Having produced alcohol by adding water to ethylene in presence of an acid capable of fixing the alcohol, why should he not add water to carbonic oxide by operating in presence of an alkali to fix the acid product? He enclosed carbonic oxide together with moist caustic potash in a flask, which he then heated in boiling water. After several hours, the gas was entirely absorbed. On distilling with sulphuric acid, he obtained formic acid, identical with that produced by the ant.

The artist cannot always rise to sublime heights. During several years only minor works were produced by the young composer: he was gathering strength for an effort of surprising importance, which enabled him, in 1860, to write

the first part of the monumental fourth and final movement of his great symphony. On April 30, 1860, Berthelot announced to the Academy of Sciences the discovery of a new hydrocarbon, *acetylene*, C_2H_2 . It is true that the hydrocarbon had passed through Edmund Davy's hands in 1836, but he had not studied the gas and its composition was undetermined. Berthelot was unaware of Davy's observations when he made his discovery. The completion of the final movement of his symphony was made possible in 1862, by the crowning discovery, that acetylene could be made directly, from carbon and hydrogen, by bringing these together at the temperature of the electric arc but at no ordinary furnace temperature.

We may not be all agreed as to the corner stone of our edifice of modern chemistry: many of us think it is the carbon atom itself. Our method of building, however, is peculiar: we do not merely place brick upon brick. We mortise and tenon this and that element together, according to certain narrowly prescribed rules of our craft, producing complex units of this or that design, from which in turn, by similar means, structures of ever increasing complexity are erected. The most fundamental of structures, that from which all others may be logically derived—the foundation stone of carbon chemistry—is the 'four-square' molecule *Methane*, CH_4 . Berthelot synthesised this but by an indirect process; to the present day, we have no satisfactory method of producing it upon a large scale. His genius led him to go a step higher and to begin by uniting two atoms of carbon each coupled with an atom of hydrogen—an *endothermic process*, that is to say, one in which energy is locked up, the compound being of such a kind that more heat is given out when it is burnt than can be gained by burning equivalent amounts of ordinary uncombined carbon and hydrogen: that is why, when mixed with oxygen, it gives the very hot blow-pipe flame used in joining up tramway rails and also in cutting steel plates and forgings. For the same reason, it burns with an exceptionally luminous flame.

How Berthelot came to make the discovery is not clear: from a reference which he makes to a paper by one Quet, in 1858, it seems probable that he had been led to repeat his early observations on the effect of heat upon alcohol and to isolate a product which had escaped his notice in 1851, indicated on reading between the lines of Quet's memoir. Quet had subjected both the vapour of alcohol and the gas methane, CH_4 , to the action of an electric discharge: following the usual practice, in analysing the gaseous products, he had used an ammoniacal solution of a cuprous salt to absorb carbonic oxide. He had noted an unusual appearance, the production of a chocolate-red precipitate. We may well suppose that Berthelot was struck by this observation and that on examining the precipitate he discovered acetylene. The chocolate-red compound, in fact, is characteristic of acetylene; when acid is added to it, the gas is evolved. If this interpretation be correct, the alcohol *motif* is to be heard faintly at the beginning of the acetylene movement. It

comes out more definitely towards the close. If cuprous acetylide be warmed with zinc dust and an ammonia solution, the copper is displaced by hydrogen and the acetylene becomes ethylene—which is convertible into alcohol. This amounts to making alcohol from coal and water—such indeed is the trick the conjuror Berthelot has taught us to perform, if we so desire. Even the acetic acid *motif* is to be heard and the modern conductor already inclines to make it triumphant throughout the movement. To-day it is being made, in ever increasing quantities, from acetylene, by the action of water in presence of a mercuric salt. The acetylene is thus converted into aldehyde, which is easily changed into acetic acid, by oxidation with air under appropriate conditions. The snowball set rolling by Berthelot in 1862, long rolled scarcely noticed: a few years ago, it began to move quickly: to-day it is fast gathering size and may easily grow to be colossal. The use of acetylene only became possible when calcium carbide could be manufactured with ease and the gas could be prepared from the carbide in large quantities.

Berthelot also converted acetylene into benzene, naphthalene and anthracene, *motifs* all faintly heard in the opening movement of his symphony. Like Wagner, he brings his characters again and again upon the stage. The symphony ends with faint rumblings, a confused medley of many *motifs* as yet undefined but obviously related to the all dominant acetylene *motif*. In fact, with the Ring Acetylene, forged by Berthelot, treasure is likely to be robbed from many Rhines in the future: doubtless it will be fought for lustily by the Gods of Industry everywhere, possibly often with motives not much higher than those by which Wotan's company was moved, yet let us hope to the peaceful and proper ends of mankind.

We are thus brought to the critical moment in Berthelot's career, to the close of the imaginative, constructive period, during which he had worked with a clearly conceived logical purpose—to establish the chemist's supremacy over matter. He had effected his object and, in so doing, had rendered service to his fellow men which already it is impossible to exaggerate. We can form some estimate of the value of the service Leblanc rendered by his discovery of the soda-ash process, now all but superseded. By the discovery of acetylene, Berthelot probably put the world under a far deeper obligation: how deep time alone can show. At least the stone he laid is beyond question the veritable corner stone of our mansion chemical.

Why is it that his appointment as full Professor of Organic Chemistry at the Collège de France was to be marked by his practical withdrawal from the field he had occupied in so masterly a manner? Why is it, that, having conquered full recognition for the subject, he ceased to cultivate and develop it, making only occasional excursions into the preserves of chemistry—as when he discovered persulphuric acid (1878)? From 1885 onwards, he devoted himself almost entirely to Thermochemistry. During the 1870 war he was

forced to occupy himself with explosives. Consequently, his attention became more than ever rivetted upon thermal problems. Why was it that so complete a chemist, having displayed so vivid an imagination, suddenly gave up his art to become a mechanical worker? Perhaps, the clue is to be found in the early estimate his friend Renan formed of his character; perhaps in his own *éloge* on Regnault. After Lavoisier, excepting Liebig, he was probably the greatest intellectual force that has been known among chemists: yet, by nature, by his classical training and especially by his association with Renan, he was a philosopher. As Renan told him plainly, when he took to science, his intellectual aspirations were at war with his occupation. His outward professions seem to have been incompatible with his inward feelings—a liberal and a republican through early associations, he was yet an aristocrat at heart—a professed believer in *libre pensée*, yet bound himself by severe limitations. Brought up in the old school, he was never a convert to Gerhardtism and never assimilated our modern conceptions of molecular structure. In fact, he held the strangest views on the subject and on isomerism: they were little short of occult. Like Regnault before him, he seems to have fallen out of step with the advancing body of chemists and never to have sought to recover his place. Beginning in days of strife, before atomic and molecular conceptions were clearly developed in chemists' minds, he had reason to think lightly of theory: the result was that he never grasped the logic of the system built up especially by Cannizzaro upon Avogadro's theorem. As a matter of fact, the development of organic chemistry upon systematic lines only began in the late sixties and the seventies. Laurent died in 1855, Gerhardt in 1856; Williamson's celebrated memoir, fixing the relation of alcohol to ether, was published in 1850. Frankland's conceptions of valency were not made known until 1852. Kekulé's benzene formula was proposed in 1865. Having entered the field at this time, not long after Berthelot had synthesised acetylene, I was witness of the rapid change and the great advance then suddenly made. The syntheses effected by Berthelot, fundamental as they were, were almost too simple; they had but little bearing upon the problems of vital chemistry. Perhaps it was the appreciation of this fact that led him to seek for the special facilities for studying the activity of plants which he ultimately obtained at Meudon. Let it be confessed, he made but little use of them. Neither have others in a similar position. The present condition of agricultural chemistry and of plant and animal physiology is incompatible with our professions of knowledge: our failure to advance is due simply to the ignorance of workers: they cannot think chemically in any effective way and unless chemical training be greatly improved and made logical, there will be little improvement. The great principle at work in organic synthesis, under vital conditions, is that embodied in our modern term "condensation," which connotes simply the joining up of carbon systems through the withdrawal of the elements of water. The methods of effecting condensation only became known and used about and soon after the time of

Berthelot's withdrawal from the synthetic field : probably, he never learnt to appreciate their importance.

Like Regnault, the one object he had before him was the pursuit of truth but he too was one of those who conceived truth only in the form of figures, never in the form of the ideal, through a process of interpretation. He saw the mystic force Chemical Affinity everywhere in operation. With Pean de St. Gilles, he had followed its vagaries, with results which could but lead him to desire to obtain some definite measure of its magnitude and of its variations. At one time he was in difficulty over the formation of formic acid, misled by faulty determinations of its heat of combustion. He was anxious to develop thermo-chemical principles. He had established the case for synthesis and probably saw that it was desirable to cultivate some new subject of real importance, which might bring repute to the school. His marriage will have broadened his outlook on life and may have made him more ambitious. In any case, it is noteworthy that his change of attitude should have taken place at this time.

For some or all of these reasons, he ceased to be a constructive artist : grasping the thermometer, he became a thermalist. He all but entirely changed his manner of life and became the slave of physical measurement, as was Regnault before him. The shadow and example of the great physicist were probably upon him—or *was* the change but a reversion to the literary habits of his youth ? Is not, perhaps, the ' classical ' mind akin to the physical, in its worship of precision of expression ?

These are all questions we need to consider, in order that we may appreciate the workings of the scientific mind and formulate methods of correcting its disabilities. The student of to-day has no particular difficulty in learning the current dogmas but, having done so, he seems to be proof against understanding those of yesterday and he will resent those of to-morrow. I have been greatly struck in recent years by meeting not a few examples of this human peculiarity, even among chemists of maturity. My friends may well include me among the victims. Nothing is to me more striking than the fact, that Berthelot, who proclaimed himself anxious to learn everything and to be able, at once, to change his mind from one subject to another, should have shown himself, in practice, so insusceptible to advancing current opinion—so self-determined in his outlook, so unable to act in the spirit of *libre pensée*.

He cannot have been alive to the magnitude of his own achievement : had he been, he might have remained a chemist. The account he gave of organic synthesis in his lecture to our Chemical Society in 1863, was of the simplest possible character. In the early sixties no one could foresee what woman would dare do and little wear to-day : that she would display her lower limbs so attractively clad in a fabric fashioned primarily out of the material of tree-trunks, coal, lime and water ! Modesty forbade even the Frenchman to have such visual foresight. It was clear, that Berthelot was an empire builder

but that the empire might possibly grow to its present dimensions could not be suspected. Hence probably his desire to conquer new kingdoms. What are we to say of these? His activity during forty years was phenomenal—both in the laboratory and at the desk, in his study. He not only summarised his work and published it in book-form but also spoke and wrote much on philosophic subjects and delivered many addresses upon departed colleagues, as Secretary of the Academy of Sciences. Among these, attention may be specially called to his analysis of Lavoisier's work and of his unpublished note-books, a masterly study all young chemists should read. He devoted a great amount of time to investigation of alchemical and other early literature. Here, as in all other fields, he was a pioneer and did service in directing attention to the subject. It is admitted, however, that he was much misled by the use of faulty translations, so that his work in this field is not now regarded as of the importance that was at one time supposed.

His thermochemical work stands to-day in much the same position that his synthetical work stood in in the middle sixties. As a pioneer, he was full of anxiety to map out an all but unknown land of great promise and to report its dominant features, so that others might be attracted to their study. Naturally and necessarily, the observations he recorded while constantly upon the march were not of the accuracy and abiding value required in a final prolonged survey. The accounts he gave in his many memoirs were full of fascination. Like Regnault before him, in later years, he suffered the fate of all pioneers carrying but a marching equipment: others entered the field more heavily armed, using abstruse methods which made little appeal to him. The subject is now in a state of suspended animation, needing above all others concerted inquiry under proper leadership: it is out of fashion for the time being; its importance has to be again recognised. A need such as hose and "undies" are creating for acetic acid must be discovered, to give it popularity and entice organised attack. It is beyond question, that an exhaustive study of carbon in all its supposed forms and of hydrocarbons generally, especially of the isomeric paraffins, would be of the greatest value.

Berthelot's work on the biological side shows him once more, in the main, as a chemist with undeveloped biological feeling. He will naturally have been attracted to the study of the fermentation process in the course of his work on sugars and because of the attention called to the subject by Pasteur's researches. His first efforts were made in the dark ages, before the vital character of the phenomena had been appreciated. He studied the effect upon sugar of certain animal substances—chopped testicular matter, for example—and did not realise that the liquids became infected with organisms, which determined the fermentative changes. I well remember how unfavourably I was impressed

by this work, in very early days, when the controversy between Liebig and Pasteur was being waged. Berthelot, however, made a really valuable contribution to the fermentation inquiry, in 1860, when he studied the formation of invert sugar under the influence of yeast. Pasteur had supposed that the action took place under the influence of the acid (succinic acid) formed within the organism. Berthelot was inclined to believe that the change was purely chemical and secondary, independent of any direct action of the organism. He was able to show that 'an agent' separable from the yeast was the cause of inversion: in fact, he was the first to take notice of the enzyme invertase and of its 'catalytic' activity. Later on, in 1877-78, he was involved in a controversy with Pasteur over the nature of the fermentation process proper, initiated by the posthumous publication which he undertook of certain notes discovered among Claude Bernard's papers. In these, Bernard seemed to cast doubt upon Pasteur's conclusion, that fermentation was life without air and that the sugar molecule fell to pieces, as it were, as a consequence of the withdrawal from it by a vital act of the organism of the oxygen it required. Berthelot also argued against this proposition but without bringing forward any new experimental evidence. It is obvious that he thought of the fermentation process in terms of synthetic change—as we all do, since Buchner's discovery of an enzymic mechanism by which, apart from the living cell, sugar is resolved into alcohol and carbon dioxide; the clearness of his outlook is to be gathered from the following statement:

En tout case, la science m'a toujours paru, comme à lui. Bernard tente à réduire l'action des ferments à des conditions purement chimiques, c'est à dire relativement simples mais indépendants de la vie.

At Meudon, Berthelot naturally turned his attention to the assimilation of nitrogen by plants and ultimately made the discovery that organisms in the soil were primarily responsible for its fixation. It is to be supposed that he was helped to this result by the knowledge of Pasteur's work. The discovery came at a most opportune time, when Hellriegel and Willfahrt were seeking an explanation of the nature and function of the nodular growths on the roots of leguminous plants: it was, therefore, of great theoretical importance, in settling the long outstanding controversy as to the possibility of plants utilising atmospheric nitrogen. None the less, if we ask whether the large amount of work Berthelot did at Meudon be of any *practical* value to agriculture, the answer we cannot well avoid is: 'NO'. This, however, may equally be said of nearly all agricultural "research" work (chemical and physical and most bacterial), both in this country and the U.S.A., though to a less extent in Germany, where more often a practical issue is involved. In large part the work cannot be called Research: it is just pottering. Considering the vital importance of agriculture to the community, it is incumbent upon us to revise our procedure without delay and seek to ascertain if we cannot serve practical ends, whilst working in accordance with the canons of scientific method.

We greatly need a man with *Geist*, a Liebig, to write the story of Agricultural Science: its shortcomings, its infinite, unseen opportunities; who will raise it from its present low level of academic impotence and place it upon the high rails of considered practice: make it of constructive use, in fact?

At Meudon, we see Berthelot once more the chemist, this time engaged not in synthetic but in minute analytic inquiry—yet advisedly with the object of penetrating into the secrets of Nature's synthetic activity. With infinite patience, over long periods, by a most tiresome series of minute laboratory operations, he secured exact data from which he was ultimately able to draw his conclusions. The work appears all the more remarkable when contrasted with the feverish activity he displayed in his thermo-chemical studies. He began to write a nitrogen symphony in 1868, selecting prussic acid as *motif* and making this most interesting of chemical materials, the one that is so greatly beloved of suicides, directly from acetylene and atmospheric nitrogen—thereby lowering this latter from the proud position of "don't care" aloofness which it had previously enjoyed.

The theme was a magnificent one and the movement of surpassing interest. He made use in this work of the spark discharge. In later work, he used the "silent" discharge, often at surprisingly low potentials: some of this work needs reconsideration.

Off and on, during many years, he was engaged upon a long rambling composition which has never interested chemists particularly, in studying the fixation of nitrogen upon organic matters, upon the soil, finally upon the plant itself. We have yet to put meaning into this movement of the symphony. Berthelot clearly thought of the fixation of nitrogen as coincident with the oxidation process, whether in the plant or under the influence of the electric discharge. The third movement, written in the earlier years at Meudon, already referred to, has a triumphant theme—the fixation of nitrogen within the minute bacterial edifice. That the process plays an all important part in Nature's simple synthetic scheme, we may regard as beyond all question. Berthelot, however, also thought of nitrogen as being constantly assimilated, by the soil itself, under the influence of "atmospheric electricity," apart from any vital process. It is problematic, at least, to what extent such a process may contribute to our maintenance. He even thought that nitrates might be formed within the plant, because of the very large proportion present in some species. The argument is of uncertain value, however. Hence the symphony remained unfinished: but no scientific symphony can ever be finished by one man and it is not only open to others to continue its composition, with or without promise of material reward: it is their simple duty, as Renan indeed saw.

Berthelot believed that science must ultimately exercise a great influence upon Society, both moral and material. In himself, however, he illustrates the obstacle our human nature opposes to rational regimentation. Having

learnt to write $C = 6$, $o = 8$, he could never be persuaded that it was desirable, still less that it was imperative, to double both numbers. We talk glibly of teaching scientific method, yet rarely use it ourselves, always partially, if at all: few could define it in a way to gain full marks.

As to the material consequences, these may be very great. We see them crowding in upon us, owing chiefly to the phenomenal development of engineering. That Berthelot looked far ahead is clear from the following statement he made:—

“The social outcome of laboratory discovery is not to be judged or minimised by reference to what has been learnt from the past. The day is perhaps near when the progress of chemistry will make it possible to manufacture foodstuffs economically. When that day arrives, the cultivation of wheat and the raising of cattle will meet with the fate that we have seen fall upon the cultivation of madder. There will be immense shifting of interests but the masses will profit from the change. Is it to be believed that any legislation can permanently arrest the progress of the social revolution that will follow such a discovery?”

What are we to say to this dream of his, that synthetic chemistry may upset the social apple-cart? *Per contra*, is it not possible, that æsthetics will be taught in the future as well as if not before science; that man is so much nearer to the æsthetic than he is to the scientific, that he will eventually impose a control over those who with the aid of science, so-called, would deprive him of all joy in life—all belief in Nature, all love of the beauty and perfection of her methods? To-day, already, the æsthetic palate shrinks from the manufactured, chemically hardened abomination called Margarine—it will do so still more when it knows it to be what is euphemistically called ‘improved’ with the aid of advitants from the livers of animals all and sundry. Surely, in the interest of the farming community, we should resent the displacement of the cow and insist upon pure natural butter, just as we shall insist upon pure natural milk—when we have displaced the Ministry of Health by a rational body, without fads, which will walk without fear of bacteria, realising that they are at least as often our friends as our foes.

Berthelot, in helping to show that man may make all things, has done much to hasten a débâcle. To-day there seems to be an insensate desire abroad, especially in the U.S.A., to manufacture everything, in order that wages may be earned by superabundant populations—so bent on taking the work out of Nature’s hands that they flock to the towns, where they seek to imitate her and, out of working hours, visit ‘the Pictures’ on the chance that they may occasionally be there reminded of her real existence—or they overspend their incomes upon motor cars, in order that they may hastily call upon her at the week-end. The process is akin to that of a community living by taking in its own washing: some day, it must have an unfortunate end: man will again awaken to the knowledge that he is of the earth, earthy; that he has hands of his own—even glory in using them to serve ends for which they were evolved.

The continual urbanisation of the people cannot go on for ever: some change must be made in our educational system. Here again we need to displace the artificial, manufactured article, called the Board of Education, chiefly "made in Oxford," by some rational, practical, natural body which will insist that schools and colleges are not run merely in the interests of crammers and examiners: which will see to it that they serve the masses and promote joy in life, not the inability to understand it in the least.

It is not clear what Berthelot supposed might serve as the raw material of our food—whether it would be coal? If so, we have to consider how long this would stand the demand made upon it. We cannot well make everything from coal. I fancy he went further and thought of wafers and tablets—or should it be tabloids?—taking the place of square meals, forgetting that we have stomachs that ask to be filled. Still, these may prove to be a mere detail: one surgeon, I believe, contends that they are. I remember, however, that my late friend Starling, who had lost his, once told me that he was always hungry. Berthelot may well have been in advance of his time, anticipating, in his mind's eye, our modern discovery of advitants. These do afford chemists an opportunity of which advantage has already been taken in the case of insulin and thyroxin. By putting a little real chemistry, analytical first, synthetic afterwards, into the study of these mysterious and powerful entities, we might well advance the welfare of the community in ways beyond all present dreams. If the agricultural chemist were a chemist and not the dullest and least imaginative possible of those making a profession—in more ways than one—of research, he would long since have turned his attention to the study of quality in the food given to animals—it is patent, that on the average, they do not get what is good for them. Grass, we know, is not the same grass everywhere—it varies from field to field, all over the country and month by month. It is worth eating by the cow during perhaps three months in the year. This, maybe, is a question of ratios, of balance of constituents—perhaps it is a question of advitants. No one knows. Why does not someone make a serious attempt to find out? We may well leave the infinitude of soil bacteria to their own devices for a time. We may well give up all "scientific" play with sulphur, as an antifuge, leading to no practical improvement in its use. We should certainly abolish all the useless statistical treatment of results which are not open to rational treatment of any kind, because of the number and ever varying character of the factors that are operative. The manurial trials that are carried on *ad nauseam* may well be suspended. Instead, let us put our money into robbing the grass of the field of its great secret and when it is found use it on behalf of the cow. Milk being the primary food of man, if we had real milk all the year round, with the aid of some homœopathic adjunct, there is no knowing what diseases would not lose their terror. There is much sane work to be done in agricultural and synthetic chemistry before we get down to the insane.

Berthelot has given manufacturing chemists enough to do for some time to come without their interfering with our food. At no distant date, maybe, alcohol will be made on a very large scale by his method, using the same source of ethylene as he used—coal gas. Formic acid will be manufactured by his process if and when it be required. For most purposes, the cheaper acetic acid can be used. This is already made on a large scale from acetylene: should the production of acetylcellulose silk* be extended, it may well be required in colossal amounts. If some day coal tar fail us, benzene too may be made from acetylene. Berthelot's methods are also being applied to produce many simple variants of the substances he synthesised: thus his carbonic oxide is combined with ammonia to give formamide, a substance likely to have many applications. Carbonic oxide is also combined with hydrogen to give methylic alcohol and this, in turn, is oxidised to formaldehyde, one of the most important synthetic agents in the chemist's *syncabulary*—the primary condensing material used in the production of artificial resins, one of the most interesting being that made from formaldehyde and urea, itself producible from carbon dioxide and ammonia.

Berthelot is said to have derived no profit from any of his discoveries. The least we can do, in acknowledgment of the immense debt industry owes to him for his services to synthetic science, is to recognise the greatness of his achievements: in our memory ever rank him among the famous men of chemistry.

In preparing this essay, I have been greatly aided by the masterly summary of Berthelot's career by Schützenberger, published by the French Chemical Society in 1913.

DISCUSSION.

THE CHAIRMAN said that M. Berthelot had done a great deal of propaganda work in disseminating the knowledge of new sciences amongst large classes in France. He had the art of explaining new principles and new ideas in very good and clear French, which was a very difficult task, as anyone who knew the French language well would agree.

SIR WILLIAM POPE, K.B.E., F.R.S. (Professor of Chemistry,[†] University of Cambridge) said that one of the easiest things for a chemist to do was to give an account of the life of Berthelot. One of the most difficult things for a chemist to do was to give an account of the life of Berthelot showing how the enormous amount of work which he had done during upwards of 50 years fitted in with the great scheme of progress of chemistry and had led to the present situation. Professor

* Thanks to the courtesy of British Celanese, Ltd., there was a considerable display at the meeting of very beautiful dress fabrics made from acetylcellulose.

Armstrong had not accepted the first easy task but he had taken the second one, and he was quite sure the audience would agree with him in thinking that Professor Armstrong had fulfilled that task in a way that all would have wished.

It was a very difficult matter for any of those present—all comparative juniors to Professor Armstrong—to see exactly the way in which the work of a man like Berthelot fitted in with the great scheme of progress and, as it were, on the one hand aided, and on the other hand was aided by, the general progress which was going on. It required someone like the lecturer, who had lived through that great epoch and who had himself taken part in many of the big movements which had occurred, to be able at the present time to show that way.

He had been asked to open the discussion. He was, however, a student of Professor Armstrong. He rejoiced that he was able to be present to see in him that same physical ability, the same intellectual activity and the same, if he might put it so, invective criticism at which he had marvelled, and before which he had sometimes trembled, 40 years ago. The audience would understand that a student could not open a discussion on what his professor had said. Therefore all he personally could do that evening was to express his great delight at having been present to hear Professor Armstrong give a very charming discourse, which would remain in the *Journal* of the Royal Society of Arts as a historic document for the study of students of the future. Whilst they had had that evening a discourse by the senior of English chemists on one who was recently the senior French chemist, there was perhaps one other subject which was worthy of comment. The Chairman had told an English audience not very long ago that his grandfather had learned the English language as a prisoner of war in this country some 125 years ago; and he could not help wondering whether the bond of sympathy which had then been established between the Chairman's ancestors and this country was not responsible for those present having had the honour of greeting him there that evening so appropriately when they met in celebration of the centenary of a great French chemist. The misfortune of one man was very often the good fortune of many others, and he thought the misfortune of the grandfather of the Ambassador of the French Republic was possibly the good fortune of many present that evening.

MR. ROBERT LUDWIG MOND, F.R.S., said the audience had had the privilege of listening to a very great address on a very great subject. Professor Armstrong had pointed out that, through his contact with Renan, the mind of Berthelot had been turned towards philosophic speculations. One of the consequences of this had been that when he turned his mind to chemistry he tested the question of synthesis as a whole. Some synthetic compounds had already been discovered, but Berthelot had tested the question as a whole. Berthelot had synthesised alcohol, acetylene, ammonia and a large number of other products, and then had written his book on the methods of synthesis. Then he had discovered that there were peculiar problems—which puzzled him—with regard to the rate of production of heat in chemical compounds. That had interested him very much, with the consequence that he had been led on to the question of thermo-chemistry. Still falling back on his classical training, Berthelot started his history on chemical research. He had had translated for him the writings on science of the early Greeks, and the Arabic writings on chemistry, and he had carried on that work until practically the last day of his life. He had done numbers of other things any one of which would have made him celebrated as one of the master minds in chemistry. Berthelot had not been concerned with the economic result of this work; he had been merely trying to test his philosophic conceptions, and in so doing he utilised chemistry as a tool.

He (the speaker) agreed with Professor Armstrong that chemistry was perhaps the most powerful tool which the human mind possessed in testing philosophical conceptions. In chemistry one could check one's own errors; in other sciences one could not. Consequently he had always regarded chemistry as the greatest moral training which nature had put at our disposal for the improvement of our minds and of ourselves. That was a view which, he was afraid, had not been so heartily taken up as it might have been, but it had always to be borne in mind that chemistry qua chemistry was the best tool for moral training that we possessed. The one great thing which had to be provided for was the ever increasing numbers of mankind—that they should be rationally provided for, and that was what chemists were endeavouring to do. Berthelot had shown many years ago that under the action of electrical induction, hydrogen and nitrogen could form ammonia. Years afterwards Crookes had pointed out that unless the world learned how to manufacture ammonia it would run short of food-stuffs. Now the world was manufacturing that ammonia to such an extent that there was difficulty in disposing of it. That showed the progress which was being made at the present moment, and it was a progress which was increasing in geometrical ratio. The world owed that progress to master minds such as that of Berthelot and those who had succeeded him.

MR. T. C. SUTTON said it gave one pleasure at any time to testify to universal genius. Perhaps no such thing had ever really existed, but approaches to it had been made, and Berthelot was one of the most close and successful of those approaches. In addition to the phases of Berthelot's character which had been mentioned that evening, there was another phase to which attention might be drawn, namely, his very great political activity and his enormous political ability. As Minister of Public Instruction his work had been very great, and for one brief period he had been Minister of Foreign Affairs, and had been one of the very first to see what everybody now all agreed with, namely, that the future welfare of Europe was largely dependent upon the co-operation of the French and the British peoples. When Berthelot became Minister of Foreign Affairs in 1895 his aim had been to settle all outstanding differences. The question of Siam had been settled immediately, as had also been the question of French Indo-China.

In his negotiations with Lord Salisbury Berthelot had outlined something very similar to the League of Nations. He had pointed out in official letters to Lord Salisbury that if France and England formed a union for peace, and settled all outstanding questions, they might hope to achieve something like a European United States.

DR. E. F. ARMSTRONG, F.R.S., said at that late hour all he could do was to add his tribute to the memory of Berthelot as one of the founders of chemical science, particularly on the synthetic side. Everyone appreciated and paid tribute to the discoveries of a pioneer, but it would be less easy in the future to associate one man specifically with any future discovery in the world of chemistry. Berthelot had the advantage of dealing with simple substances, and as an individual unaided he had more or less been able to solve the problems involved; but the problems which were before the world of chemistry today demanded team work, and a hundred years hence the discoveries of today would have to be tagged with a multitude of names, or with perhaps no names at all, rather than with the name of an individual. It was, therefore, well that people should be reminded occasionally that chemistry was not impersonal but very personal, and that it was individual genius, individual

holy fire, and the training and inspiration which a man got from his friends—often from acquaintances—which led him to the ultimate goal. From that point of view the lecture that evening, and all that had been heard about Berthelot recently, pointed a very important moral.

On the motion of the Chairman, a hearty vote of thanks was accorded to Professor Armstrong for his lecture.

PROFESSOR ARMSTRONG, in acknowledging the vote, said he particularly desired to thank His Excellency the French Ambassador for having paid the Royal Society of Arts the honour of presiding that evening. They had recently had an experience of French hospitality in Paris. Nothing could have been more delightful. On all occasions there could be no greater pleasure than to be brought into contact with French men of letters and French men of science; the members of the Society were, therefore, particularly grateful to His Excellency that evening for his kindness in attending.

On the motion of Mr. L. B. Atkinson, a vote of thanks was heartily accorded to H.E. the French Ambassador for presiding, and the meeting then terminated.

MEETINGS OF THE SOCIETY.

ORDINARY MEETINGS.

Wednesday evenings at 8 o'clock.

JANUARY 18.—ARTHUR HENRY BARKER, B.Sc., B.A., M.I.E.E., Wh.Sch., "Methods of Radiant Heating." PROFESSOR A. E. RICHARDSON, F.R.I.B.A., Professor of Architecture, University College, London, will preside.

JANUARY 25.—H. DE KONINGH, "Enamels." DONALD WIPPELL, Esq., will preside.

FEBRUARY 1.—CHARLES HERBERT WRIGHT, B.A., "Modern Aspects of Rubber Cultivation." SIR DAVID PRAIN, C.M.G., C.I.E., M.B., LL.D., F.R.S., will preside.

FEBRUARY 8.—HENRY D. WILKINSON, M.I.E.E., "Theatre Lighting." ALAN A. CAMPBELL SWINTON, Esq., F.R.S., Vice-President of the Society, will preside.

FEBRUARY 15.—CAPTAIN SIR BEACHCROFT TOWSE, V.C., K.C.V.O., C.B.E., "The Education of the Blind."

FEBRUARY 22.—H. R. H. HALL, M.V.O., M.A., D.Litt., F.S.A., F.B.M., Keeper of the Department of Egyptian and Assyrian Antiquities, British Museum, "Recent Discoveries at Ur."

FEBRUARY 29.—ARCHIBALD CRAWFORD, K.C., Director of the Economic League. "Industry Fifty Years Hence." THE RT. HON. G. N. BARNES, P.C., C.H., Member of the Council of the Society, will preside.

MARCH 7.—J. H. JEANS, M.A., D.Sc., F.R.S., Secretary of the Royal Society. "Some Wider Problems of Cosmogony." (Trueman Wood Lecture.)

MARCH 14.—HAROLD G. BROWN, M.I.E.E., of the D.P. Battery Co., Ltd., "Lead Storage Batteries."

MARCH 21.—CAPTAIN SIR ARTHUR CLARKE, K.B.E., Elder Brother of Trinity House and a Member of the Council of the Society, "Trinity House: its History and its Work." ADMIRAL OF THE FLEET SIR HENRY B. JACKSON, G.C.B., K.C.V.O., F.R.S., M.I.E.E., will preside.

APRIL 18.—ALFRED C. BOSSOM, F.R.I.B.A., "American Architecture."

INDIAN SECTION.

Friday afternoons, at 4.30 o'clock.

JANUARY 20.—MAURICE G. SIMPSON, M.I.E.E., Director-in-Chief, Indo-European Telegraph Department, "The Indo-European Telegraph Department." SIR GEOFFREY CLARKE, C.S.I., O.B.E., late Director General, Posts and Telegraphs, Government of India, will preside.

FEBRUARY 10.—SIR EDWARD A. GAIT, K.C.S.I., C.I.E., "Ancient Bihar and Orissa." (Sir George Birdwood Memorial Lecture.) THE RT. HON. VISCOUNT CHELMSFORD, G.M.S.I., G.C.M.G., G.M.I.E., G.B.E., will preside.

MARCH 9.—LIEUT.-COLONEL I. A. E. EDWARDS, C.M.G., Deputy Director, Air Transport, Department of Civil Aviation, Air Ministry, "The Future Prospects of Civil Aviation in India." COLONEL THE MASTER OF SEMPILL will preside.

DOMINIONS AND COLONIES SECTION.

Tuesday afternoons at 4.30 o'clock.

JANUARY 31.—THE RIGHT HON. LORD LOVAT, K.T., K.C.M.G., K.C.V.O., C.B., D.S.O., "Migration in the Empire." THE RIGHT HON. THE EARL OF CLARENDON will preside.

FEBRUARY 28.—SIR STEPHEN MONTAGU BURROWS, C.I.E., "The Ancient Civilisation of Ceylon."

MAY 22.—CAPTAIN SIR CECIL ARMITAGE, K.B.E., C.M.G., D.S.O., "Gambia" (illustrated by lantern slides).

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

ALBERT ERNEST DUNSTAN, D.Sc., F.I.C., F.C.S., "The Scientific Foundation of the Refining of Petroleum." Three lectures. January 16, 23 and 30.

H. GOUGH, "Fatigue Phenomena, with special reference to Single Crystals." Three lectures. February 13, 20 and 27.

A. G. HUNTLEY, May Construction Company, Ltd., "Acoustics." Three lectures. April 16, 23 and 30.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK:

MONDAY, JANUARY 2. Automobile Engineers, Institution of, at the Merchant Venturers' Technical College, Bristol, 6.45 p.m. Mr. E. A. Watson, "The Electrical Characteristics of Spark Gap and Sparking Plugs."

Chemical Industry, Society of, at Burlington House, W. 8 p.m. Dr. J. C. Drummond, "The Future of Biochemical Research."

Geographical Society, at the Æolian Hall, 135, New Bond Street, W. 3.30 p.m. Dr. E. H. Marshall, "The Royal Research Ship 'Discovery' in the Antarctic."

Swiney Lecture, at the Royal College of Science, South Kensington, S.W. 5.30 p.m. Dr. Robert Campbell, "The Geological History of Scotland." (Lecture VII—"The Old Red Sandstone" (continued).)

Transport, Institute of, at the Institution of Electrical Engineers, Savoy Place, W.C. 5.30 p.m. Mr. L. G. Wyndham Shire, "The Use and Maintenance of Pneumatic Tyres as applied to Commercial Vehicles."

TUESDAY, JANUARY 3. Automobile Engineers, Institution of, at the Royal Society of Arts, Adelphi, W.C. 7.45 p.m. Mr. C. K. F. Engelbach, "Some Notes on Motor Engineering Works to Increase Production."

North East Coast Institution of Engineers and Shipbuilders, at Middlesbrough, 7.30 p.m.

Royal Institution, 21, Albemarle Street, W. 3 p.m. Prof. E. N. da C. Andrade, "Engines" (Lecture III) "Engines which work to and fro."

Wireless Technology, Institute of, at the Engineers' Club, Coventry Street, W. 7 p.m. Mr. E. H. Turle, "The Relation Between Anode Current Consumption and Reaction Coupling."

WEDNESDAY, JANUARY 4. Architects, Royal Institute of British, 9, Conduit Street, W. 4 p.m. Mr. C. H. B. Quennell, "Every day Things in the Middle Ages." (Juvenile Lecture.)

Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m.

Heating and Ventilating Engineers, Institution of, at Carlton Hall, Broadway, Westminster, S.W. 7 p.m. Mr. G. Urquhart Morgan, "Oil Fuel Burning for Central Heating and Domestic Boilers."

Microscopical Society, 20, Hanover Square, W. Meeting of the Biological Section.

Swiney Lecture, at the Royal College of Science, South Kensington, S.W. 5.30 p.m. Dr. Robert

Campbell, "The Geological History of Scotland." (Lecture VIII—"The Carboniferous System.")

THURSDAY, JANUARY 5. Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m.

Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m. Mr. E. C. McKinnon, "Storage Batteries in Relation to Modern Supply of Electric Lighting and Power."

Linnean Society, at Burlington House, W. 5 p.m.

Mechanical Engineers, Institution of, at Manchester. Mr. E. G. Herbert, "Cutting Temperatures: Their Effect on Tools and on Materials subjected to Work." (Joint Meeting with the Manchester Association of Engineers.)

Royal Institution, 21, Albemarle Street, W. 3 p.m.

Prof. E. N. da C. Andrade, "Engines (Lecture IV)—Engines which Work round and round."

FRIDAY, JANUARY 6. Architects, Royal Institute of British, 9, Conduit Street, W. 4 p.m. Mr. C. H. B. Quennell, "Every day Things in the Renaissance." (Juvenile Lecture.)

British Empire Producers' Organisation, at the Royal Society of Arts, Adelphi, W.C. 4.30 p.m.

Chemical Industry, Society of, at Milton Hall, Deansgate, Manchester. 7.30 p.m. Mr. F. C. Wood and Miss Agnes Alexander, "The Action of Caustic Alkali on Partially-Methylated Cellulose—The Heat of Reaction and Absorption."

Geographical Society, at the Æolian Hall, 135, New Bond Street, W. 3.30 p.m. Mr. C. F. Key, "Abyssinia and the Blue Nile."

Geologists' Association, at University College, Gower Street, W.C. 7.30 p.m. Dr. A. Brammall, "Dartmoor Petrified"; Mr. A. W. Groves, "Eocene and Pliocene Outliers between Chislehead and Headley"; Mr. F. T. Ingram, "The Petrology of the Srisbury Sandstone."

Mechanical Engineers, Institution of, Storey's Gate, S.W. 6 p.m. Professor C. J. Hawkes, "The Marine Oil Engine." (Thomas Lowe Gray Lecture.)

Photographic Society, 35, Russell Square, W.C. 7 p.m.

Meeting of the Pictorial Group.

Swiney Lecture, at the Royal College of Science, South Kensington, S.W. 5.30 p.m. Dr. Robert Campbell, "The Geological History of Scotland." (Lecture IX—"The Carboniferous System" (continued).)

SATURDAY, JANUARY 7. Royal Institution, 21, Albemarle Street, W. 3 p.m. Prof. E. N. da C. Andrade, "Engines (Lecture V)—Putting the Furnace in the Cylinder."

JOURNAL OF THE ROYAL SOCIETY OF ARTS

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FRIDAY, JANUARY 6th, 1928

All communications for the Society should be addressed to the Society, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK.

WEDNESDAY, JANUARY 11th, at 3 p.m. (Dr. Mann Juvenile Lecture). PROFESSOR ARTHUR SMITHELLS, C.M.G., D.Sc., F.R.S., Director, Salters' Institute of Industrial Chemistry, "Flame" (Lecture II). The lecture will be fully illustrated by experiments. Tea will be served in the library after the lecture.

COMPETITION OF INDUSTRIAL DESIGNS.

The fifth annual Open Competition of Industrial Designs will be held in June next, and full particulars can now be obtained on application to the Secretary of the Royal Society of Arts.

Competitions will be held in the following sections :—Architectural Decoration, Textiles, Furniture, Book Production, Pottery and Glass, and Miscellaneous. Over £1,600 will be offered in prizes and scholarships in the various sections.

After the work has been judged a number of selected designs will be exhibited in London, and subsequently at suitable centres in the provinces. In this way they will be brought immediately to the notice of those manufacturers who are likely to be specially interested in them.

It is intended to confer the Society's Diploma on any candidate whose work reaches a very high standard of artistic ability and also shows practical knowledge of the materials and processes of his trade.

A Bureau of Information has been established at the Royal Society of Arts for the registration of the names and addresses of exhibitors who desire to obtain employment as designers. These lists are at the service of manufacturers in search of designers.

The following Scholarships and Prizes for Designs are offered for competition ;

GENERAL.

DONOR.	PRIZE.	DESIGN.
James H. Hyde, Esq.	£100 (Travelling Scholarship).	Designs shewing greatest merit in the Architectural Decoration or Textile Sections.
Royal Society of Arts (Art Congress Student-ship Trust).	Art Congress Student-ship of £50. (Founded by the late Sir William Cuthbert Quilter, 1906).	Designs of greatest merit or promise in any Section.

ARCHITECTURAL DECORATION.

Messrs. Lewis Berger & Sons, Ltd.	£60 (Scholarship).	
Royal Society of Arts (John Stock Trust).	£50.	Entrance Hall to a Cinema.
Messrs. Bagnès, Ltd.	£50.	Wrought Iron Canopy for Main Entrance of a Theatre.
Messrs. Shanks & Co., Ltd.	£31 10s. (First Prize). £15 15s. (Second Prize).	Bathroom in Private Mansion.
M. Adams-Acton, Esq.	£25.	Petrol-filling Station.
Royal Society of Arts (Swiney Trust).	£25.	Silver Cup for the Swiney Prize.
Chairman of Architectural Decoration Committee.	£15.	Decorative Fountain.

TEXTILES.

Messrs. Simpson and Godlee, Ltd.	£52 10s. (First Prize). £31 10s. (Second Prize). £21 (Third Prize).	Cretonne.
Messrs. Tootal Broadhurst Lee Company, Ltd.	£75 (Travelling Scholarship).	Printed and Woven Dress Goods, and Printed Furnishings.
Messrs. Arthur H. Lee and Sons, Ltd.	(a) £20 (First Prize). £10 (Second Prize).	Printed Linen or Cotton Furnishing Fabric in the "modern" style.

DONOR	PRIZE.	DESIGN.
	(b) £20 (First Prize). £10 (Second Prize).	Printed Tapestry or Moquette for Fur- niture Covering in the "modern" style.
Messrs. G. P. and J. Baker, Ltd.	£31 10s. (First Prize). £21 (Second Prize).	Printed Cloth.
Messrs. F. W. Grafton and Co., Ltd.	£30 (First Prize). £15 (Second Prize).	Printed Linen.
Messrs. Tomkinsons, Ltd.	£20 (First Prize). £10 (Second Prize).	Axminster Carpets.
Messrs. John Crossley and Sons, Ltd.	£30.	Axminster Carpet.
Messrs. Story & Co., Ltd.	£15 15s. (First Prize). £10 10s. (Second Prize).	Printed Linen.
Messrs. Warner & Sons.	£21.	Silk Fabrics.
Messrs. A. Herbert Woolley & Co., Ltd.	£20.	Lace.
The Wallpaper Manu- facturers, Ltd.	£10 10s.	Wallpaper.
Mrs. Lewis F. Day.	£10.	Embroidery.

In all the sub-sections of the Textile Section additional prizes of £10 and £5 may be awarded by the Royal Society of Arts if, in the opinion of the Judges, any designs of sufficient merit, to which other prizes are not awarded, are submitted.

FURNITURE.

Members of the Fur- niture Section Com- mittee.	£20 (First Prize). £5 (Second Prize).	Oak Furniture for a Dining Room.
„ „	£20 (First Prize). £5 (Second Prize).	Walnut Furniture for a Drawing Room.
London Cabinet and Upholstery Trades Federation.	£20 (First Prize). £5 (Second Prize).	Bedroom Suite in Modern Style.
A West-end Firm.	£10 10s.	Dining Room Chairs.
The Star Manufacturing Company.	£10.	Decoration of Side Panels of a Baby Carriage.
The Cabinet Maker.	£5 5s.	Cabinet for a Wire- less Receiving Set.

BOOK PRODUCTION.

Seven Prizes of £10 10s. each are offered in this section.

POTTERY AND GLASS.

Six Prizes of £10 10s. each are offered in this section.

MISCELLANEOUS.

DONOR.	PRIZE.	DESIGN.
Messrs. W. McKenzie and Co., Ltd.	£25 (Two First Prizes). £15 (Two Second Prizes). £10 (Two Third Prizes).	Christmas Cards and Calendars.
Messrs. Simpson and Godlee, Ltd.	£52 10s.	Poster advertising "Bevis Fabrics."
Messrs. C. C. Wakefield and Co., Ltd.	£50.	Poster or Showcard advertising "Wakefield Castrol Motor Oils."
Henley's Tyre and Rubber Co., Ltd.	£50.	Poster advertising the Company's Pneumatic Motor Tyres.
Messrs. J. S. Fry & Sons, Ltd.	Two First Prizes of £15 15s. Two Second Prizes of £7 7s.	Poster advertising Fry's Breakfast Cocoa and Showcard Advertising Fry's Easter Eggs.
The Empire Marketing Board.	£25 (First Prize). £10 (Second Prize). £5 (Third Prize).	Shop Window Bill.
Messrs. Rowntree and Co., Ltd.	£25 (First Prize). £10 (Second Prize). £5 (Third Prize).	Window Display Piece.
Messrs. Joseph Nathan and Co., Ltd.	£25 (First Prize). £5 5s. (Second Prize).	Poster advertising Glaxo or Glax-ovo.
Messrs. W. T. Henley's Telegraph Works Co., Ltd.	£25.	Showcard advertising the Henley Wiring System.
Messrs. Hodder and Stoughton, Ltd.	Three Prizes of £5 5s. each.	Designs to be placed at the head of Press Advertisements of (1) Novels ; (2) General Books ; (3) Religious Books.
Messrs. Catesbys, Ltd.	£10.	Booklet Cover.

PROCEEDINGS OF THE SOCIETY.**SIXTH ORDINARY MEETING.**

WEDNESDAY, DECEMBER 7TH, 1927.

CAPTAIN SIR ARTHUR WELLESLEY CLARKE, K.B.E., Elder Brother of Trinity House, in the Chair.

THE CHAIRMAN, in introducing the lecturer, said that Mr. Duly was a Master of Arts, and had gained the Mitchell Student Prize for 1925-26 for the very subject on which he was about to address the Society that evening. He was sure that when Mr. Duly had finished his lecture those present would go away with a good deal more knowledge of the sweating of cargoes than they had possessed before. Personally he was an old sailor and had carried many millions of tons of cargo. He could go back for something like 68 years, and he knew all about the difficulties and dangers connected with cargo due to sweating. He was confident that had he known as much about the matter as the audience were going to learn from Mr. Duly, there would have been much less damage done to the cargo which he used to carry.

The following paper was then read :—

THE DAMAGE TO CARGO DUE TO "SHIP'S SWEAT."

By S. J. DULY, M.A.,

Head of the Department of Commercial Products, City of London College,
Mitchell Student for 1925-6.

Moisture is a common agent of damage to goods stored in warehouse, cold store or in ships' holds. Its manifestations are extremely varied. Among them the following instances may be enumerated to illustrate the range of commodities affected by moisture and the variety of the symptoms attributable to its influence.

The loss of the power of germination of seeds shipped overseas in bags is a fairly common occurrence and is due principally to dampness. Great care must be exercised in the carriage of grain in bulk to see that the moisture content of the grain is below a safe maximum ; otherwise the grain begins to ferment and heat "spontaneously." The growth of moulds is a familiar consequence of the presence of moisture ; aeroplane spruce, for instance, is difficult to carry without the development of fungal damage unless it is dry, appropriately stowed and ventilated. Shell eggs carried or held in cool storage just above freezing point not infrequently become covered with the white filaments of moulds which penetrate the shells and spore abundantly within the eggs. Low temperatures do not prevent fungal growth if the moisture conditions are favourable, so that in the carriage of frozen meat, and specially of chilled meat, the abolition of mould is a matter requiring care.

Bacterial activity also requires moist conditions, and a variety of instances of damage from this cause might be given. The rusting of metallic objects, such as canned goods, and the tarnishing and corrosion of galvanised plates are still further examples of damage which would be absent if it were not for circumstances which allow them to become moist.

The holds of cargo vessels are usually bone dry. The visible presence of moisture is an abnormal state of affairs. If it does occur it is derived either from the cargoes carried or else from the ventilating air. This general statement disregards the possibility of rain or sea water reaching the ships' holds as accidents outside the scope of the discussion.

Many cargoes which would be regarded as dry, such, for instance, as graded wheat or air-dried timber, contain, nevertheless, a comparatively high percentage of water. Wheat arrives in this country with a moisture content between 11.5 and 14 per cent. On a long voyage the grain dries out to the extent of from $\frac{1}{2}$ to 1 per cent., and this represents a considerable weight of water on a cargo of three or four thousand tons, which is gently carried away by the ventilating air. The weight of grain delivered from the ship is thus about $\frac{3}{4}$ per cent. less than the weight shipped, and a large part of this loss is due to drying. Timber dries in a similar manner on certain voyages. It follows that apparently dry cargo provides a source of moisture, in the same manner as, but to a less extent than, damp cargoes, such as unseasoned timber or low grades of raw sugar. Damage by moisture derived from cargo is generally thought of as the chief and perhaps only form of sweat damage on board ship. To be more logical it should not be regarded as due to ship's sweat, but to the sweating of cargo, the ship's iron structures offering a condensing surface on which the moisture from the cargo is precipitated when the conditions are appropriate.

The air entering the ventilators provides the second source from which moisture in the hold may be derived, and it is mainly with damage arising from this cause that this paper is concerned. The condensation of moisture from the ventilating air in the holds of vessels should receive another name to distinguish it from the sweating of cargo. If the term "ship's sweat" were reserved for moisture derived from cargo, the term "condensation" or "condensation damage" might be used to denote moisture derived from the ventilating air, and the damage it causes.

The occasional and sometimes frequent arrival in this country of shipments of canned goods in a rusty condition from the Pacific Coast of the United States of America, and from British Columbia carried via the Panama Canal, provided the occasion of the investigation into the manner in which ventilating air may start damage. The rusting leads to a depreciation of, perhaps, ten per cent. of the sound value of the goods, because it is necessary either to sell at a reduced price or to unpack, recondition, re-label and re-pack the tins. The contents are unaffected unless the rusting is bad enough to cause perforation

of the metal. The condition on arrival of such a shipment is worth a careful description since at least half the difficulty in discovering the cause lay in an accurate diagnosis of the symptoms of damage.

The cans are packed in pine boxes, nailed together and bound with galvanised wire. Externally these packing-cases are entirely free from blemish. Sometimes their uniform cleanness and brightness on arrival in London is astounding, for when they are unpacked the tins are seen to be speckled with rust. The rusting varies in severity from case to case. Some are lightly speckled and some heavily. The only indication on the outside of the cases that the goods within are not in perfect condition is that the heads of the nails of the case may be touched with rust and the binding wires tarnished. But these slight symptoms are too insignificant to lead one to anticipate damage within. The distribution of the rust spots is noteworthy. They occur on either or both ends of the tins—there are two tiers of tins in each case—and under the labels. Their distribution is sporadic and not confined to the contact between the rims and the wood of the packing-case. Where there happens to be a loose knot or broken slat in a case the damage extends inwards heavily from the opening.

Sometimes a consignment arrives with the wood of the packing cases badly discoloured. Such a consignment may be a parcel of another mark stowed in with canned goods, such as those just mentioned, as arriving externally clean, and, therefore, subject to the same conditions as those on the voyage. Usually two or three sides of such a case are greenish black, like old weathered soft-wood. This confuses the issue, because it appears to point to damp timber as the origin of the moisture which has settled on the cans; moreover, such externally damaged cases are the most readily observed and have received the most attention from surveyors. The arrival of one small consignment of such blackened packing cases proliferously covered with the minute black fruit bodies of the timber fungus *Ceratostomella pilifera* fixed the cause of the blackening. The boards from which the blackened slats were cut were infected from the beginning, and the conditions in the ship's hold humid enough not only to cause the timber to become penetrated by the fungus, but also to cause it to produce perithecia abundantly.

The confusion is made worse by the occasional presence of stained cases containing perfectly clean and bright cans, either on the same voyage when rusted cans are turned out from other parts of the vessel's hold or on other voyages when all the cans are free from rust.

There are other minor indications of damage which need not here be catalogued, but which hinder the recognition of the main characteristic of this damage, namely, that rusted goods are contained within clean packing cases. The fact is that the variety of symptoms correspond to no single cause, but to a main cause producing rusted cans within clean cases and other secondary and minor causes operating simultaneously, producing other and minor symptoms.

The rusting of canned goods carried through the Panama Canal has been studied on the American side by Dr. A. W. Bitting, who attributed the cause generally to condensation of moisture on board ship, and recommended a thorough investigation into the effect of ventilating the cargo. The opinion in London was divided as to the cause because of the variety of the symptoms. The use of damp packing cases and the liberal use of paste on the edge of the label were held to be at least contributory causes, and the frequent appearance of fungi both on the sapwood of the timber and on the labels were put forward to support that view; that the main damage was due to over-humid conditions in the holds of the vessel was also held to be a likely cause, but exactly how this could produce such rusting was difficult to explain. In order to make tin plate rust in the manner of the damaged tins it is necessary for actual beads of moisture to become deposited on it. It will not rust simply by being kept in humid air, unless temperature changes operate to cause the deposition of moisture upon it. The problem then was to investigate these moisture and temperature conditions on board ship in an endeavour to define the circumstances in which moisture from the incoming air could become deposited on the cargo. The records of this investigation, which was carried out on a summer voyage in 1926 to Vancouver, and a second summer voyage this year to New York, lead me to differentiate between three classes of condensation of moisture in the ship's hold, and to focus attention on the lag which exists between the temperature of cargo and the temperature of air and sea when the latter are changing fast. The three classes of condensation are as follows :-

- (1) Moisture condenses on the ship's side while the cargo remains dry.
- (2) Moisture condenses on the cargo while the ship's side remains dry.
- (3) Moisture condenses on the under-side of the deck and hatch coamings and drips back on to cargo.

The circumstances in which each of these forms of condensation arises differ from each other; in addition the method of ventilation necessary to check the condensation depends on the particular form.

The principle underlying all investigations of this kind is that dew will form on any object if it is cold enough to be below the dew point of the air reaching it. An instance of this may be given from the occasional formation of dew on the deck of a vessel passing through tropical waters.

At mid-day, or soon after, the deck reaches a temperature of 120°-125° F. As late afternoon approaches the deck cools fast, and by six o'clock it is colder by a few degrees than the air, for the air temperature has not fallen as fast as the deck. The deck reaches the nightly level of 82-83° before the air, and if the air on these occasions approaches saturation it becomes covered with dew. In what circumstances can such deposition of moisture take place in the ship's hold?

To discover this we must look for temperature differences in the ship either between day and night or from day to day, which would cool some internal part of the ship or cargo sufficiently to cause moisture to condense out on it.

The controlling factor in regulating the temperature of the lower holds of the ship is the temperature of the sea water. The hull of the vessel is immersed in the sea down to her marks and only half-an-inch of steel separates the hold space from the sea water. The steel is a good conductor and its temperature is that of the sea water, so that the "walls" of this "warehouse" are at the temperature of the sea water. The scrutiny of a typical record of the sea water temperatures on a voyage from the United Kingdom to Los Angeles through the Panama Canal discloses an absence of fluctuations that comes as a surprise to one accustomed to conditions on land. The best instance is in tropical seas, for instance, across the Caribbean Sea and into the Pacific Ocean. Here the temperature remained constant day and night at 83° F. with a fluctuation of only + and - 1 in the neighbourhood of the land masses of Central America. The sea is a huge thermostat, so that goods in the lower holds are maintained at a constant temperature day and night while the vessel is in tropical waters.

On the voyage from England to the tropics, the sea water temperature rises gently and with regularity. There is the general upward trend due to the change in latitude, amounting to an average of 2.5°-3° F. per day, and superimposed upon this is a daily fluctuation of + or --1 due to the sun, being rather greater in higher latitudes than in lower. The changes in temperature in the lower hold due to the influence of sea water are consequently very gradual, and no large difference exists between the day and night temperatures of the sea water to produce periodic nightly saturation of the air in the hold. Sudden changes in the temperature of the sea water do, however, occur on the voyage, and these are due to ocean currents the approximate positions of which are known to the officers of the ship. For instance, the ship leaves the North Equatorial Current off the Gulf of California, sailing north to enter the cold Californian Current, and in consequence the temperature falls with great suddenness.

Turning now to the air temperatures, we shall not be surprised to find them rather more influenced by the succession of day and night than sea water temperatures are, but what is remarkable is the very close agreement between the shade temperature of the open air and the sea water temperature, throughout a long voyage. Usually the air and sea temperatures lie very close together indeed. There is the same gradual upward trend due to changes in latitude amounting to 2.5-3° F. per day until the tropical average of 83° is established, and superimposed on this upward trend is the daily rise and fall. This daily periodic change is greatest in high latitudes. Thus in the North Atlantic in fine weather it amounts to + and --4° F., while in the tropics it is nearer + or - 1° F. At no time is the daily fluctuation of the air tempera-

ture at sea as great as it is on land. When the sea water temperature begins suddenly to fall on account of ocean currents, the air temperature falls with it, the sea temperature falling rather in advance of the air temperature.

The closeness of the shade temperature of the air to the sea water temperature is well illustrated by plotting one on the other, and it will then be seen that the difference is never very great.

The significance of the shade temperature of the air lies in the fact that it is the temperature of the air entering the ship's ventilators. It is the air entering the cargo spaces. The holds of a cargo vessel are usually ventilated by cowl ventilators in groups of four, each serving all the holds within every two thwart ship bulkheads. The weather ventilators are trimmed to back the wind and act as uptakes, and the lee ventilators are trimmed to catch the wind. At each successive deck the cylindrical sheet iron pipes which carry the air to and from the holds are cut short just below the deck and are continued down with a somewhat smaller diameter to the next lower deck. The annular space thus left provides a passage for the ventilating air to enter or leave the respective hold in the 'tween-deck. The air enters and leaves the ventilators with considerable speeds, and although these speeds are related to the speed of the ship and to the prevailing wind, in practice some surprising figures are obtained by measuring the speeds of the air currents entering and leaving the ventilators, and comparing them with the speed of the wind. The fact is that the distribution of the air currents on the deck is extremely complex both in force and direction, so that it by no means follows that with a head wind of 20 miles per hour there is a current of air of that value entering the cowl trimmed to catch it. The sheer and camber of the deck, the raised fo'c'stle, the presence of deck erections and the resistance offered by the bridge all influence the force and direction of the air currents in the immediate neighbourhood of the cowls, and it is these subsidiary air currents which enter the ventilators. The efficiency of the ventilators measured by the volume of air they admit in a given wind is consequently for the most part the chance of their position (including, of course, their height above the deck), relative to the deck erections, which act as shields.

Air at shade-temperature enters the holds through these ventilators at, let us say, an average speed of six miles per hour, and this corresponds to an entry of approximately 120,000 cu. ft. of air per hour into the lower hold, the volume of which may be 60,000 cu. ft. This air is at a temperature practically identical with that of the sea water, and consequently of the ship's side in contact with it. By day it may be a degree or so warmer and by night slightly colder than the sea water. No sufficient differences of temperature arise, therefore, to cause the precipitation of moisture from the incoming air on any object in the hold. It is not indeed the actual temperature of this ventilating air which is the critical figure, against which to match sea water

temperatures and the temperature of cargo, but the dew point of the ventilating air. If, however, all the objects in the hold, including the ship's side, are as warm as the air, they will be still warmer than the dew point, which is normally at least five degrees lower than the shade temperature of the atmosphere. In consequence we should not anticipate any deposition of moisture in the hold as long as the changes in temperature are the gradual ones which characterise the typical voyage from the United Kingdom through the tropics. The dew point is very conveniently measured by a recording wet and dry thermometer, although there is considerable difficulty in fixing it on the ship in such a way as to get a record uninfluenced by the radiation from deck or bulkhead. The dew point curve is then easily drawn after removing the chart, by the use of Glaisher's factors. As long as no object in the hold has a temperature below that given by the dew point curve, there can be no risk that moisture in the ventilating air entering the holds may be deposited either on cargo or on the ship's side.

We shall now observe the circumstances in which such deposition of dew "condensation" takes place inside the ship, and this may perhaps be illustrated most aptly by examples.

We had loaded oranges for Vancouver in Los Angeles Harbour. A semi-tropical sun played on the ship all day, so that when her holds were closed down to sail on the evening of July 23rd, the temperature of the air in the hold was 84° F. Outside San Pedro we sailed with amazing suddenness into the cold Californian current. At 6.30 p.m. the air entering the ventilators had a temperature of 67°, while the issuing air was 17° warmer, viz., 84°. By 10 p.m. the outside air had fallen to 63°, and that leaving the holds to 73°. By 8 o'clock on the next morning the air temperature had fallen to 55.5°, the sea water temperature to 56°, while the temperature of the air in the hold had not fallen below 64, so that the sides of the ship were covered with sweat. The cargo had not yet cooled to a temperature lower than 73°. This is an instance of the general case where a ship carrying a cargo through the tropics enters a cold current to remain in it for a period of days. Her cargo does not cool down immediately. It remains warm for some days, and the general hold temperature remains above the temperature of the sea water and the air. The ship's side is in contact with the cold sea water and becomes covered with moisture; the cargo is still very warm and is consequently safe from the possibility of condensation from it. It is the first form of condensation mentioned earlier in this paper, where the ship's side becomes covered with moisture while the cargo remains dry. The cargo has not yet cooled down and is safe from the possible precipitation of moisture upon it. The ship's side is the coldest part of the hold and it is here that the condensation takes place. The moisture on the ship's side runs down into the bilges and does not damage the cargo.

The proper course to take to keep the hold dry is to ventilate as vigorously as possible. If the ventilators are fitted with fans, these are used. The incoming air is cold, but not colder than the sea water, and consequently there can be no fear that it can contribute to the risk. If by a misfortune the ventilators had to be covered on account of heavy weather or rain the humidity of the air in the hold would continue to rise, for you then have a closed space being continually cooled from without. It is with falling temperatures that the closing of ventilators becomes dangerous, because of the increasing humidity of the hold with the consequent growth of moulds and the risk of condensation of moisture on the ship's side or under the deck and its dripping back on to cargo.

It is not, however, this class of condensation which produces the occasional extensive damage to canned goods and to galvanised and plated goods. General high humidity of the hold is not enough to cause the damage observed, especially as the cargo is warm. It is in the reversed position, when the ship sails suddenly into warm waters with a comparatively cold cargo on board, that this damage arises. As an example, canned goods are loaded at North Pacific ports in the winter months at low temperatures, and the ship puts to sea with a sea water temperature in the neighbourhood of 54° F. Down the coasts of Washington, Oregon and Northern California the sea water temperature remains low on account of the Californian current, only rising slowly as lower latitudes are reached. On reaching the latitudes of Southern California on the homeward voyage the ship encounters the North Equatorial current, and occasionally the step up in temperature occurs with marked suddenness. On every voyage the rise is large, but on some voyages the change is much more abrupt than on others. Once the rise sets in, it continues until the tropical average of 83° F. is reached, and it remains at this temperature or thereabouts throughout the succeeding ten days, while the ship is making for the Panama Canal and crossing to the West Indies. The cargo meanwhile remains cold and only warms up slowly. The ship's side is in contact with the warm sea-water. If the cargo is now ventilated, the ship's side being warm remains dry, but the metal cargo, although it is cased up, offers a condensing surface to the penetrating air, and is liable to become saturated. As long as the temperature of the cans remains below the dew point of the ventilating air, as it very well may for a considerable period, the condensation of moisture upon it continues. The hold at this time appears on inspection to be quite dry because its sides are warm. The condensation takes place within the cases and is thus unobserved.

It will be noted that the conditions are now the reverse of those considered earlier. The ventilation requirements are also reversed. To ventilate a cold cargo (and especially to use forced ventilation with warm air), is to court trouble, for the dew point of the warm air is often not more than three or four degrees below the dry bulb temperature. The aim should be to seal the hold up before the rise

in temperature sets in. If the ship enters the warm region with her cold cargo sealed up the cargo is safe: the ship's sides become warmer hourly and the decks, exposed to the sun and subject to the rise in atmospheric temperature, also get hot, and these act as warm radiators to the cold cargo. The relative humidity of the air in the holds falls as the external temperatures rise and the cargo consequently remains safe.

To what extent the temperature of the cargo lags behind that of the atmosphere and the sea-water when such a rise takes place is not known. I have begun investigations into this question in a short voyage to New York, in which I had the bulb of a mercury-in-steel long-distance recording thermometer sealed in a gallon can of water stowed with cargo in the lower hold of the vessel and recording in the upper 'tween deck.

The temperature conditions on the North Atlantic are entirely unlike those on a voyage towards low latitudes. Across the Western Ocean sea water temperatures fluctuate considerably on account of the contending influence of the Labrador and other Arctic currents setting westward and the waters of the Gulf Stream, which in these latitudes are still easily recognisable and exert a great influence on the temperatures of the sea water, although they no longer follow a well-defined course as they do in the thirties and forties. The vessel's track is across the northern edge of that part of the ocean within the influence of the Gulf Stream, and is constantly crossed by Arctic streams. The record of the temperature of the sea water on a North Atlantic voyage is consequently very irregular. However, the sudden entry into the Gulf Stream after a day's steaming from New York is well marked. On the voyage in which this experiment was carried out, the temperature of the sea water rose from 58° to 73° in four hours, and while this high temperature level was not maintained the influence of the gulf stream was felt for several days afterwards. The temperature of the can only gradually rose to that of the sea water, and when 70 hours later the vessel passed through cold water to re-enter Gulf Stream waters after 20 hours' steaming, the can hardly cooled at all. Indeed, the record of the temperature of the can shows a very smooth curve, not influenced by temporary fluctuations in the sea water temperature, but following its general trend after a time interval of something in the neighbourhood of twelve hours.

On the occasion of the rise in temperature just referred to, the air temperature rose to 75° , and for a few hours the dew point was above that of the cargo and the vessel's interior. As the rise set in the walls of the saloon and state rooms, where ports and doors were open, became heavily covered with moisture.

A word must be said with regard to the difference between air temperature and sea water temperatures on the North Atlantic. In these latitudes a change of wind results in a marked difference in air temperatures, and the close agreement existing between shade temperatures of the outside air and the sea water on such voyages as those to California, New Zealand and South Africa

does not exist. The voyage, however, across the North Atlantic is a short and cold one, and the humidity conditions which would damage cargo on a longer voyage are generally of too short duration to do harm. What experimental evidence there is, therefore, of the lag between the temperature of the cargo when external conditions are rising and falling fast shows the lag to be real and measurable. The opposite phenomenon, namely, the cooling off of warm cargo, has been investigated more closely in connection with the carriage in refrigerated holds of fruit which has not been pre-cooled. It is well known that such fruit takes many days to reach the temperature at which it is to be carried.

The new proposal with regard to the ventilation of canned goods or metal cargoes, or of any cargoes which are themselves free from moisture, is, therefore, to restrict the ventilation drastically when temperatures are rising fast, and to do this prior to the rise, and to ventilate vigorously when temperatures are falling rapidly.

Following out the likely fate of two consignments of canned goods, one ventilated according to these principles and the other ventilated whenever possible, as is the customary practice, the following position arises :

Suppose one consignment to be ventilated vigorously when the sudden rise occurs on entering tropical seas on the homeward voyage. There is a real risk that the tins will become covered with moisture, the risk depending on the temperature of the cargo and the dew point of the ventilating air. It will be observed that these two conditions must be satisfied, and it is this which accounts for the comparative rareness of instances of extensive damage. Suppose, then, that the condensation occurs at the time of the rise in temperature. The moisture will settle sporadically on the surfaces of the tins within the cases in the manner in which it is seen to have settled on arrival in this country, in cases of damage. When the ship enters the Caribbean Sea she encounters the N.E. trades, and it may be necessary to cover the ventilators to prevent spray reaching the cargo. Often it is necessary to keep ventilators closed for this reason for several days. The external temperatures are now high both day and night and the conditions for rusting and the growth of moulds on the labels and on the insides of the packing cases are set up. The hold becomes a moist incubator.

In the case of the second consignment we will suppose the ventilation shut off just prior to the rise in temperature. The percentage humidity in the hold falls and the cargo remains dry. There is no opportunity for rusting or mould growth. On leaving the tropics for the voyage across the North Atlantic it is desirable to open the ventilators, for the ship is daily entering cooler waters, although no sudden change occurs. If the holds at this stage of the journey were not opened the percentage humidity within them would continue to rise on account of the external cooling, and although this could not cause the goods to rust, since they are now the warmest objects in the

ship after having been in the tropics for 10 days, high relative humidity of the hold would encourage the growth of moulds on the cases and on the labels of the goods.

There remains the practical difficulty of modifying the ship's ventilators so that any cargo space can be ventilated or closed from the weather deck. As ventilators are now constructed it is only possible to exclude air to all levels simultaneously, and even then, in vessels with shelter decks, air would still enter through the annular spaces between the extensions of the ventilators and the ventilator coaming. In practice, a ventilator is closed by removing the cowl, plugging the coaming and securing the plug by covering it with tarpaulin, making it fast with rope. This is only carried out under stress of bad weather. To put into practice the method of ventilating now described, it is necessary to be able to close or open the ventilators to those particular holds alone in which canned goods or similar cargo is stowed. This is necessary in order to permit ventilation at the same time of a hold in which goods requiring permanent ventilation are stowed, above or below the metal goods.

The third form which condensation presents is the precipitation of moisture on the underside of the weather deck, where it collects and drips back on to the cargo. This form of condensation has long been known, and it is commonest in cases where moisture is derived from cargo; earlier in this paper reference was made to the shrinkage in weight during the voyage of cargo apparently dry. It is not perhaps sufficiently appreciated that the temperatures in a lower hold are maintained at about 83° or 84° both day and night while the ship is in tropical waters, and this is a higher and more evenly maintained temperature level than that occurring on land in the temperate countries whence much produce containing moisture is derived. Consequently it must dry out. The compulsory closing of ventilators when such cargoes are carried, therefore, leads to a rapid increase in the absolute humidity of the confined air. The deck cools towards evening, and while dew may form on deck, condensation takes place beneath it. The danger is greatest when the general trend of temperatures is downwards, and the ventilators are closed on account of the weather, in accordance with the argument already set forth.

The recognition of the three forms which condensation of moisture may take on board ship supplies the key to the confusing symptoms of damage met with when a damaged consignment of canned goods is surveyed. As long as condensation was regarded as always belonging to the last class described, namely, the dripping back from the deck head and the ship's sides and frames of moisture derived from cargo, it was impossible to explain the common occurrence of clean cases containing rusted cans. The occurrence of damaged cases from the top tiers containing sound or perhaps slightly damaged tins might be explained by such sweating. But the main damage is done by the unsuspected form of condensation on the goods themselves when temperatures are rising, while the abundant fungal growth on the outside and inside of the cases and

on the labels of the tins is brought about by the second form, when temperatures are falling.

DISCUSSION.

THE CHAIRMAN said Mr. Camps was present, and perhaps he would make some observations on the point of the possibility of having a universal system of ventilation for the different holds of a ship.

MR. H. E. J. CAMPS said it was always difficult to criticise a paper which was being read in public when one had not had an opportunity of previously perusing it in print; but he was certain that all present were indebted to the lecturer for giving them the benefit of his experience and experiments and data which he had accumulated. There were many contentious points in the paper, and personally he did not think it would be right for him to enter into them, but merely to confine himself to the particular point on which the Chairman had asked him to say a word. From a naval architect's point of view there was not the slightest difficulty in ventilating holds, or in providing a system of ventilation which would be satisfactory under all conditions. The difficulty was to get owners to agree to the cost of doing it, and, when owners had been induced to agree to it, there was the further difficulty of getting cargo owners to agree to pay the extra freight necessary to meet the expense of fitting the ship with a costly system of ventilation. Those were two essential difficulties which personally he had had the greatest trouble in meeting during the last 30 or 40 years. He thought the cost involved of fitting a system of ventilation which would overcome the difficulties of condensation and sweating would be well repaid, and he was glad to note the lecturer had made a definite distinction between sweating and condensation. There was no difficulty in devising a system of ventilation which would deal equally with both those effects, because both of them were really due to the same cause, namely, moisture, and the point was to get rid of that moisture and to prevent it from having access to the holds.

THE CHAIRMAN said it had struck him in listening to the lecture that something in the nature of a little brochure for the guidance of master mariners and officers at sea would be a very useful thing because many seamen did not understand the points to which reference had been made. He would admit at once that he had never heard of them before; but he had been away from the sea for some time. He had been given to understand by one of his colleagues at Trinity House that one of the Companies did issue such a brochure, and he would be glad if Captain Mackay would tell the audience something about it.

CAPTAIN A. S. MACKAY (Trinity House) said the brochure referred to was a valuable little document, which went thoroughly into the matter, not only from the point of view of fruit cargoes, but also many other cargoes. It had been compiled as the result of various observations made by both the administrative staff and the officers of the company. Personally he had found it extremely useful. It gave the sailorman many hints which enabled him to carry his cargo through the various conditions which had been described that evening, and keep him out of trouble. He suggested that the lecturer might put the main points of his lecture into a little brochure and publish it for the benefit of those concerned.

COMMANDER SHANKLAND (Superintendent and Chief Harbour Master, Port of London) said he took it the main object of the lecture was to impress upon the

audience that there should be a system which could be readily adjusted to changes of temperature and its effects on moisture and condensation. That was a system very much to be desired, but it had not received much attention. Most of the temperatures taken in a hold were taken for the purpose of identifying a hold with a fire and not with the purpose of seeing their effect on fruit. The most important point which the lecturer had made was that holds were rarely ventilated in proportion to the cubic area. On reflection that was very obvious. He remembered some ships in which most of the ventilators were at one end and hardly any at the other. It was, however, remarkable when one thought of a ship loading at Calcutta in a temperature of 125 deg. and discharging in London at 35 deg. how little damage was found to be done to a cargo, taking into account that big range of temperature.

MR. H. A. ABRAM (Niger Company) said he had really come to the meeting with the object of learning something about sweat damage rather than to give any information. It was a matter which had caused merchants a considerable amount of worry, and although there was a great deal in the paper which would give one furiously to think, he had been hoping that something would have been said by the lecturer about cocoa and coffee and things like that, in regard to which sweat damage was a very serious item. The difficulty was to pin down the responsible party—whether it was the fault of the ship or whether it was a combination of circumstances through which the ship had to pass. Surveyors were generally of the opinion that it was very largely the fault of the ship. His own experience of reports went to show the fact that ships were not sufficiently ventilated. He had not heard any reference that evening to dunnage boards; but when one told a shipping company that their ships were not properly ventilated they usually told one of the large number of dunnage boards which they had, and seemed to think that that was conclusive evidence that the ship was well ventilated. In many cases merchants were told that their cargoes had been sweat damaged, although those cargoes had been composed of dry goods, which had no tendency to sweat of themselves, which did not have any moisture in them, which were loaded in the sun and which went from a hot climate into a cold climate—that was, the cold air was meeting the hot cargo, and in regard to which, therefore, there could not possibly be any condensation. It seemed strange, that being the state of affairs, that merchants should so frequently be told that their cargoes were sweat damaged. He had heard it rumoured that some shipping companies persuaded surveyors to return the goods as anything but sweat damaged because they did not wish to give the impression that their ships were not well worked. That was a point on which he would like to hear the lecturer. There was no doubt that ships' holds when examined in Hamburg and Amsterdam were simply running with water. He took it that this occurred when the ship got nearer land owing to changes in temperature, and that probably sweating did not occur so much on the voyage. The merchant's side of the matter was sometimes not always very much considered. The shipowners and surveyors seemed to have it all their own way, and it was extremely difficult for a merchant to set aside a decision of a gentleman who claimed to be an expert. He hoped the lecturer would be able to give some particular information about sweat damage to cocoa.

THE CHAIRMAN asked Mr. Freeman, of the Port of London Authority, if he could give any information with regard to cocoa.

MR. JOHN FREEMAN replied that he had had no definite experience of the effect of moisture on cocoa. He was the deputy of the engineer who was responsible for

the maintenance of warehouses in which cargoes were stored, and he was glad to hear of the progress which was being made in the rectification of faults and conditions which brought about defects in cargoes carried to ports like the Port of London. It would tend to reduce the ill-condition of cargoes when they arrived into the custody of port authorities, whose responsibility thereby would be very greatly diminished. His Port certainly stored cocoa, but he had no information that there was any damage to the cocoa berries when they arrived.

THE CHAIRMAN asked Mr. Freeman if he could give any information about the possibility of condensation or sweating in the Port of London warehouses and cold storages, and, if there was that condensation or sweating, in what way it was rectified.

MR. FREEMAN said the majority of cold storages were ventilated very thoroughly. The whole system depended on circulation of air. That was fundamental, as the lecturer had emphasised. His Authority did not get damage due to condensation or sweat, provided everything was carried out properly.

THE CHAIRMAN said that it appeared that ventilation was an exceedingly important factor both on sea and on shore.

MR. FREEMAN agreed.

MR. L. W. GOLTON (Committee of Lloyds) said as a clerk on the staff of the Committee of Lloyds he had to depend very largely on the reports of experts, and it was very difficult for a mere insurance clerk to dispute the statements of gentlemen who termed themselves experts. He could say, however, that it was the experience of those on the staff of the Committee who had to deal with matters of this nature, that in many cases which came to their notice it could be proved, on thorough investigation, that the people responsible for the management of the ship would do their work infinitely better had they clear and concise instructions as to how to manage cargoes. If such a brochure as the Chairman had referred to could be published, not in technical terms but in simple language, he was certain great good would result.

MR. C. J. TABOR said he spoke as a surveyor of 35 or 40 years experience. He did not agree with the lecturer on the subject of the growth of mould being due to a decrease or increase in temperature; low temperatures retarded but did not prevent it. In his opinion infection always occurred before initial refrigeration. The aerobic mould germs were ubiquitous and ever present in the atmosphere; they were very capricious organisms. If two carcasses of sheep were prepared for refrigeration the germs might fall on one sheep and not affect the other in the slightest degree. One fertile source of trouble was the paste with which labels were stuck on to goods, if it had not been first treated. With regard to fruit, people entirely ignored the fact that a fruit was a living organism, and unless it were given ventilation it was certain to go wrong.

MR. DULY, in reply, said with regard to the question of a brochure, he did not feel at all competent to draw up such a document. So many different cargoes got stowed together in holds, that almost every stowage plan required a different set of rules. He had thought of the possibility of putting forward some fairly simple rules for use on board ship, but he had always drawn back because so much experience was

needed in order to lay down simple rules, which were much harder to lay down than complicated ones. One simple rule, however, with regard to canned goods was "Do not ventilate when the temperature is going to rise fast." He believed, that certain shipping companies did circulate among their own staffs some such document—it might be simply a list of cargoes with their peculiarities.

He was sorry to say he knew nothing about cocoa, but he assumed that cocoa was no more dry than wheat or timber. Then it was a seed ; whether it was dead or not he did not know. He had no knowledge of the question, but it looked like one of the problems in which the water which produced the sweat damage was derived from the cargo itself.

THE CHAIRMAN said he was sure cocoa had moisture in it.

Mr. DULY said perhaps the restriction of the moisture content in the cocoa cargo to some maximum would get over the trouble.

THE CHAIRMAN was sure the audience would join with him in according a hearty vote of thanks to Mr. Duly. Mr. Duly had had an extremely good audience—as good an audience as he had seen since he had become a member of the Society. It had been a very attentive audience—an audience mostly composed of young men ; they always learned something at the Royal Society of Arts, and it was the young men who were wanted to come to the Society's meetings and learn.

The vote of thanks was carried unanimously, and a vote of thanks to the Chairman concluded the meeting.

NOTES ON BOOKS.

IN A PERSIAN OIL FIELD. By J. W. Williamson. London : Ernest Benn, Ltd., 1927.

This book, which the author rightly describes as a study in scientific and industrial development, gives in broad outline an account of the work the Anglo-Persian Oil Company is doing in applying scientific knowledge and methods in the oil industry. Mr. Williamson does not pretend to give a technical summary of the operations involved in finding, getting and refining crude oil ; he went out to Persia to see how far the work of the Anglo-Persian Oil Company in that country was an example of the application of science to industry, and to observe the human and sociological factors involved in the huge operations of the Company.

After describing the Persian oil fields he goes on to deal with methods of finding the oil, drilling the well, the gas problem, the pipe line and methods of refining the crude oil ; great stress is placed on the importance of the work done at the research stations at home and abroad.

The second part of the work deals with the Medical and Public Health Services in the Company's Area of Operations ; the housing of the staff, the workshop training of the native workers and schools for their children. The author's easy style and the numerous illustrations help to make this a most readable book.

METINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, JANUARY 9. Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Award of Prizes and Studentships, and Criticism by Mr. L. Sylvester Sullivan on work submitted.

Electrical Engineers, Institution of, Savoy Place, W. 7 p.m. Mr. A. E. Loe, "Portable Power Appliances." At the University, Liverpool. 7 p.m. Captain P. P. Eckersley, "Technical Principles of Broadcasting." At Armstrong College, Newcastle-on-Tyne. 7 p.m.

Geographical Society, at the Æolian Hall, 135, New Bond Street, W. 8.30 p.m. Dr. T. G. Longstaff "The Nanda Devi Problem."

Metals Institute of, at 39, Elmbank Crescent, Glasgow. 7.30 p.m. Open Discussion on various subjects.

Surveyors' Institution, 12, Great George Street, S.W. 8 p.m. Mr. Cecil H. Bailey, "The Reports of the Royal Commission on Mining Subsidence."

Swiney Lectures, at the Royal College of Science, South Kensington, S.W. 5.30 p.m. Dr. Robert Campbell, "The Geological History of Scotland." Lecture X: Permian, Triassic, Jurassic and Cretaceous Systems.

TUESDAY, JANUARY 10. Asiatic Society, 74, Grosvenor Street, W. 4.30 p.m. Mrs. Ayscough, D.Litt., "Court Life in the T'Ang Dynasty as illustrated by the Life of Tu Fu."

Automobile Engineers, Institution of, at Broadway Café, Coventry. Mr. M. Platt, "The View-Point of the Owner-Driver."

Civil Engineers, Institution of, Great George Street, S.W. 6 p.m. Sir Dugald Clerk, "Standards of Thermal Efficiency for Internal-Combustion Motors."

Colonial Institute, at the Hotel Victoria, Northumberland Avenue, W.C. 8.30 p.m.

Electrical Engineers, Institution of, at the Hotel Metropole, Leeds. 7.15 p.m. Mr. H. T. Harrison, "The Problems of Public Lighting by Electricity." At the Engineers' Club, 17, Albert Square, Manchester. 7 p.m.

At the North British Station Hotel, Edinburgh. 7 p.m. Mr. E. C. McKinnon, "Storage Batteries in relation to Modern Supply of Electric Lighting and Power."

Mine Engineers, Institute of, 85-88, The Minories, E. 6.30 p.m. Mr. T. R. Thomas, "The Effect of Type and Disposition of Machinery on the Strength of Ships."

Metals, Institute of, at the Armstrong College, Newcastle-on-Tyne. 7.30 p.m. Mr. George Mortimer, "Permanent Mould Casting in Aluminium Alloys."

Optical Society and Physical Society, at the Imperial College of Science and Technology, South Kensington, S.W. 8 p.m. Mr. A. Whitaker, "Progress in the Recording and Reproduction of Sound."

Petroleum Technologists, Institution of, at the Royal Society of Arts, Adelphi, W.C. 5.30 p.m. Dr. L. Dudley Stamp, "The connection between commercial Oil Deposits and major Structural Features with special reference to Asiatic Fields."

Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. A. C. Banfield, "Bridges, Pictorial and Otherwise."

Quekett Microscopical Club, 11, Chandos Street, Cavendish Square, W. 7.30 p.m. Mr. C. C. Swatman, "Cleaning Mud Gatherings for Diatoms." Mr. M. Burton, "Deep Sea Sponges and the beauty of their Structure."

Royal Institution, 21, Albemarle Street, W. 3 p.m. Prof. E. N. da C. Andrade, "Engines (Lecture VI) Heat Engines which produce Cold."

Transport, Institute of, at the Institution of Electrical Engineers, Savoy Place, W.C. 6 p.m. Mr. E. Havers, "Some Aspects of the Legal Side of Air Transport." At the University, Bristol. 5.30 p.m.

WEDNESDAY, JANUARY 11. Analysts, Society of Public, at 30, Russell Square, W.C. 8 p.m. The following papers will be read:—Mr. J. R. Nicholls, "The Determination of small quantities of Benzoic and Cinnamic Acids, with some notes on the Colorimetric Determination of Salicylic Acid"; "A Rapid Method of Determining Sulphur Dioxide"; and four additional papers by the Preservatives Determination

Committee of the Chemists of the Manufacturing Confectioners' Alliance, Food Manufacturers' Federation.

Civil Engineers, Institution of, Great George Street, S.W. 6 p.m. Mr. Roger T. Smith, "The Effect of Acceleration and Deceleration on the Wear of Railway Track."

Electrical Engineers, Institution of, at the Cleveland Technical Institute, Middlesbrough. 7 p.m. Mr. J. H. Parker, "Electricity in the Home."

Fuel, Institute of, at Burlington House, W. 6 p.m. Mr. A. B. Scorer, "The Utilisation of Town's Refuse and Refuse Fuels."

Geological Society, Burlington House, W. 5.30 p.m. Mr. G. Martin Lees, "The Geology of South-Eastern Arabia."

North-East Coast Institution of Engineers and Shipbuilders, at the Cleveland Technical Institution, Middlesbrough. 7.30 p.m. Mr. G. Booth, "Colliers."

Optical Society and Physical Society, at the Imperial College of Science and Technology, South Kensington, S.W. 8 p.m. Mr. V. E. A. Pullin, "Recent Applications of X-Rays."

Swiney Lectures, at the Royal College of Science, South Kensington, S.W. 5.30 p.m. Dr. Robert Campbell, "The Geological History of Scotland." Lecture XI: Scotland during Tertiary Times.

THURSDAY, JANUARY 12. Electrical Engineers, Institution of, at University College, Dundee. 7.30 p.m.

Historical Society, 22, Russell Square, W.C. 5 p.m. Miss E. M. Carus-Wilson, "The Merchant Adventurers of Bristol in the 15th Century."

London Society, at the Royal Society of Arts, Adelphi, W.C. 5 p.m. Mr. H. Genocchio, "Antiquities and Romance of His Majesty's Customs."

Mechanical Engineers, Institution of, at the Hotel Metropole, Leeds. Mr. Lawford H. Fry, "High Pressure Compound Locomotives."

At Glasgow. Mr. E. G. Herbert, "Cutting Temperatures: their Effect on Tools and on Materials."

Metals, Institute of, at 83, Pall Mall, S.W. 7.30 p.m. Dr. G. D. Bengough, "Corrosion with special reference to Standard Tests."

North-East Coast Institution of Engineers and Shipbuilders, at the Mining Institute, Newcastle-on-Tyne. 6 p.m. Mr. J. Calderwood, "Diesel Engine Drive for Generators and other Auxiliary Machinery on board Ship."

Oil and Colours Chemists' Association, at 8, St. Martin's Place, W.C. 7.30 p.m. Mr. R. G. Daniels, "Some Points in the Manufacture of Zinc Oxide."

Optical Society and Physical Society, at the Imperial College of Science and Technology, South Kensington, S.W. 8 p.m. Dr. J. W. T. Walsh, "Artificial Daylight."

Photographic Society, 35, Russell Square, W.C. 7 p.m. Meeting of the Colour Group.

Refrigeration, British Association of, at the Institution of Mechanical Engineers, Storey's Gate, S.W. 5.30 p.m. Dr. T. Moran and Mr. E. C. Smith, "The Conditioning or Ripening of Beef."

FRIDAY, JANUARY 13. Chemical Industry, Society of, at Burlington House, W. 8 p.m. Mr. H. K. S. Clotworthy, "The Manufacture of Artificial Silk: with special reference to Viscose."

Engineering Inspection, Institution of, at the Royal Society of Arts, Adelphi, W.C. 7.30 p.m. Mr. P. Dunsheath, "Some Interesting Points in the Operation of Dielectrics."

Malacological Society, at Burlington House, W. 6 p.m.

North-East Coast Institution of Engineers and Shipbuilders, Newcastle-on-Tyne. 6 p.m. Mr. J. Calderwood, "Diesel Engine Drive for Generators and other Auxiliary Machinery on board Ship."

Philological Society, at University College, Gower Street, W.C. 8 p.m. Dr. W. Perrett, "Greek Music."

Transport, Institute of, at the Midland Hotel, Manchester. 6.30 p.m. Mr. L. C. Harris, "Some Aspects of Shipping Transport." At the Town Hall, Newcastle-on-Tyne. 5 p.m. Paper by Mr. W. J. Merrett.

Swiney Lectures, at the Royal College of Science, South Kensington, S.W. 5.30 p.m. Dr. Robert Campbell, "The Geological History of Scotland." Lecture XII, The Quaternary Period.

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FRIDAY, JANUARY 13th, 1928.

All communications for the Society should be addressed to the Society, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK.

MONDAY, JANUARY 16th, at 8 p.m. (Cantor Lecture). ALBERT ERNEST DUNSTAN, D.Sc., F.I.C., F.C.S., "The Scientific Foundation of the Refining of Petroleum." (Lecture I).

WEDNESDAY, JANUARY 18th, at 8 p.m. (Ordinary Meeting). ARTHUR HENRY BARKER, B.Sc., B.A., M.I.E.E., Wh.Sch., "Methods of Radiant Heating." PROFESSOR A. E. RICHARDSON, F.R.I.B.A., Professor of Architecture, University College, London, will preside.

FRIDAY, JANUARY 20th, at 4.30 p.m. (Indian Section). MAURICE G. SIMPSON, M.I.E.E., Director-in-Chief, Indo-European Telegraph Department, "The Indo-European Telegraph Department." SIR GEOFFREY CLARKE, C.S.I., O.B.E., late Director General, Posts and Telegraphs, India, will preside.

Tea will be served in the library from 4 o'clock before the Meeting.

THOMAS GRAY MEMORIAL TRUST.

PRIZES FOR THE IMPROVEMENT AND ENCOURAGEMENT OF NAVIGATION.

Under the above trust the Council offer the following Prizes :—

(i) A Prize of £100 to any person who may bring to their notice a valuable improvement in the Science or Practice of Navigation proposed or invented by himself in the years 1927 and 1928.

In the event of more than one such improvement being approved, the Council reserve the right of dividing the amount into two or more prizes at their discretion.

Competitors must forward their proofs of claim on or before December 31st, 1928, to the Secretary, Royal Society of Arts, John Street, Adelphi, W.C.2.

(ii) A Prize of £50 for an essay on the following subject:—

“The Practice of Navigation in the Mercantile Marine.”

The essay must be based on the actual methods used by the writer during his career, with special reference to the instruments used as aids to navigation, and the effect of stowage of cargo on the steering, speed and safety of the vessel.

Competitors must send in their essays not later than December 31st, 1928, to the Secretary, Royal Society of Arts.

The essays must be typed or clearly written. They must be sent in under a motto, accompanied by a sealed envelope enclosing the author's name.

The Judges will be appointed by the Council.

The Council reserve the right of withholding the Prize or of awarding a smaller Prize or Prizes, if in the opinion of the Judges no suitable essay is submitted.

The Council also reserve an option on the copyright of the successful essay.

DR. MANN JUVENILE LECTURES.

The first of two juvenile lectures on “Flame,” given under the Dr. Mann Trust was delivered on the afternoon of Wednesday, January 4th, by PROFESSOR ARTHUR SMITHELLS, C.M.G., D.Sc., F.R.S., Director of Salters' Institute of Industrial Chemistry.

SIR PHILIP MAGNUS, Bt., Chairman of the Council, presided.

In the course of this lecture, Professor Smithells, after illustrating the getting of fire from flint and steel, tinder, and the sulphur match, took up the candle flame and shewed how the idea arose that “flame is burning smoke.” He explained why this should be corrected into “flame is burning gas,” and by experiments shewed that, whether we have solids, liquids, or gases to begin with, the flame is always burning gas or vapour. He then explained the structure of ordinary flames, their shape, and their hollowness. Passing then to coal gas flames he demonstrated by experiments the principle underlying the Bunsen burner, which in one form or another is the gas burner now used in all gas appliances either for heating or lighting. He exhibited a number of experiments with his cone-separating apparatus illustrative of the scientific principles involved and concluded by showing the specially beautiful phenomena to be observed in the flame of cyanogen. In the course of his lecture Professor Smithells made allusions to matters of practical importance in the use of flames and encouraged his juvenile audience to try to think out the explanation of some of the characteristics of a candle flame, about which they could learn a good deal by careful observation and some very simple experiments that he suggested.

On the motion of Professor H. E. Armstrong, F.R.S., a vote of thanks was accorded to Professor Smithells for his interesting lecture.

PROCEEDINGS OF THE SOCIETY.

INDIAN SECTION.

FRIDAY, 9TH DECEMBER, 1927.

SIR CAMPBELL RHODES, C.B.E., in the Chair.

THE CHAIRMAN, in introducing the lecturer, said the subject for discussion that evening impinged very closely on the question of free trade versus protection. A friend of his who liked to put a little truth into his jests once remarked about him (the speaker) that he was a protectionist or free trader according to whether he was East or West of Suez and neutral in the neutral zone of the Suez Canal. He suggested that the speakers that evening should impose upon themselves a self-denying ordinance as far as possible and confine their remarks to the particular subject of the Tariff Board. That Tariff Board had been very successful in its personnel and in its Presidents, and had been backed up by the very big brain of the Government of India, Sir Charles Innes, who was at present on his way to take up the Governorship of Burma, and Sir Charles was ably supported by his Lieutenant, Sir David Chadwick, the lecturer that evening, who therefore had a first-hand knowledge of the subject he was going to speak upon.

The following paper was then read :—

THE WORK OF THE INDIAN TARIFF BOARD.

By SIR DAVID T. CHADWICK, C.S.I., C.I.E.

February 16th, 1923, was a notable day in the life of the first Indian Legislative Assembly. It also marks a definite event in the economic history of India. On that day the Assembly accepted without a division a Government resolution drafted in the following terms :

- " That this Assembly recommends to the Governor General in Council
- (a) that he accepts, in principle, the proposition that the fiscal policy of the Government of India may legitimately be directed towards fostering the development of industries in India ;
 - (b) that, in the application of the above principle of protection, regard must be had to the financial needs of the country and to the present dependence of the Government of India on import, export and excise duties for a large part of its revenue ;
 - (c) that the principle should be applied with discrimination, with due regard to the well-being of the community and to the safeguards suggested in paragraph 97 of the Report of the Indian Fiscal Commission ;
 - (d) that in order that effect may be given to these recommendations, a Tariff Board should be constituted for a period not exceeding one year in the first instance, that such Tariff Board should be purely an investigating and advisory body and should consist of not more than three members, one of whom should be a Government official, but with power, subject to the approval of the Government of India, to co-opt other members for particular enquiries."

For the first time India had adopted protection as an integral part of its fiscal system. It was a deliberate act, done after detailed enquiry, in full consideration of the political and economic conditions of India at the time, and adopted after a long debate in the Legislative Assembly. As worded, the resolution embodied the principal recommendations of the Indian Fiscal Commission—of which Sir Campbell Rhodes and Sir Reginald Mant were distinguished members. This Commission had been appointed, some 18 months previously, to examine, with reference to all the interests concerned, the Tariff policy of the Government of India. It had toured throughout India, examining many witnesses and recording much evidence. As a result of its deliberations it had recommended the adoption of what it described as a “policy of discriminating protection”—a policy which in some other countries has since been described as one of “selective” protection.

I am not concerned this evening with the merits of that policy or with the arguments with which it can be defended or assailed. It is sufficient for my purpose to state it, to point out what it avoided and what it involved, and then to describe how it is being implemented and with what results. One point in connection with it must have already attracted your attention. About 200 words were required to frame the resolution enunciating this policy—far too many to provide a convenient political label or an easy battle cry. In fact, the policy did not adopt the word “Protection” as a fetish. It expressly avoided any idea of the preparation of a long and comprehensive table of protective duties covering all kinds of industries, which would be presented *en bloc* to the country and Assembly for consideration. That method renders impossible the presentation of all the data on which such proposals are based and opens the doors for eager bargaining and lobbying.

Although the policy was enunciated so as to endeavour to avoid many features which have characterised the introduction of protection in many countries, it was not a negative policy. It contemplated very definite action—the adjustment of the Indian customs duties to assist, in certain conditions, selected industries, always bearing in mind the general interests of the community and the financial needs of the State. This forecast the division of the Indian tariff schedule into two parts, one in which the duties are determined by the fluctuating revenue needs of the State, and the other in which the duties are determined by the need for protection of selected industries which satisfy certain given conditions.

Any industry was free to apply for protection, but, if it did so apply, it would have to prove that it satisfied the conditions laid down in paragraph 97 of the Report of the Indian Fiscal Commission. In brief those conditions were :

- (a) that the industry possesses natural advantages ;
- (b) that without the help of protection it is not likely to develop at all or not so rapidly as is desirable ; and

- (c) that it will eventually be able to face world competition without protection.

These conditions still leave no guidance on a most practical point, namely, the rate at which protection should be given. On this the Fiscal Commission laid down that, where protection is given, it must be "adequate but not excessive." They pointed out that increases in duties on the ground of protection, but insufficient to attain their object, only laid an unnecessary burden on the country.

When the policy was first enunciated many were inclined to regard all these safeguards and conditions as entirely illusory, as mere words and phrases calculated to deceive the hesitant.

It was quite clear that the reality which they could be given would depend mainly, if not almost solely, on the thoroughness with which the authority entrusted with the investigation into an application for protection carried out its investigations, and the form in which it presented its recommendations. This task—an unenviable one—was to be entrusted to a Committee of three, designated the Tariff Board. In regard to this body the Fiscal Commission recommended that

- (a) it must command the confidence of the country ;
- (b) it must be above any suspicion of subservience to any interests ;
- (c) it should have sufficient permanence to ensure consistency in its decisions ;
- (d) it should be entirely free from all administrative functions ;
- (e) it should be purely advisory and deal with definite applications for protection remitted to it by the Government for investigation.

Tariff Boards or Tariff Commissions have been appointed in other countries with somewhat analogous duties, but none of these served as an exact model. There was no question here of a number of *ad hoc* committees each dealing with different industries, and each working out its own experience for itself. That might be a more rapid way of getting through a number of applications, but thereby experience in dealing with such applications would be lost, and the danger of inconsistent decisions arising from different methods of work increased. Nor was the Tariff Board to adjudicate on disputes arising from the interpretations of the tariff—that was a function of the Customs Administration and the Law Courts. Nor was the Tariff Board to conduct any general surveys of industries or of economic conditions. Its business was to test, by the conditions laid down, applications for protection remitted to it for enquiry and to make recommendations, and in doing so to build up a method of procedure and a tradition for dealing with such cases.

Great insistence was laid by the Fiscal Commission on the need for the utmost publicity, both in the course of the enquiry, in the presentation of results and in the publication of the report. It was recognised that occasions would arise in which an industry could legitimately ask that certain details

required by the Tariff Board should be treated as confidential, but both for enabling the Tariff Board to arrive at the truth, and for inspiring in the country confidence in its procedure and final report, the greatest importance was attached to the utmost publicity at every stage. Throughout its work the Tariff Board has been guided by this advice ; and it has established a position in which, whilst confidential evidence is not shut out, the tendering of it is avoided as far as possible, because it has been realised by applicants that by claiming to give evidence in confidence, they risk raising in the minds of the public a certain amount of prejudice against themselves. In fact, this insistence on publicity throughout the enquiry has made several, who were inclined to apply for protection for their industries, reconsider carefully their position and the completeness of the case they could make out for State assistance.

The Tariff Board does not receive applications for protection direct. Such applications are made to the Government and if they consider there is a *prima facie* case are referred to the Tariff Board for enquiry. The Tariff Board is thus not a Court to whom anyone can apply of his own motion. It is not diverted from the course of its enquiries by the need of sitting as an admission Court or by the consciousness of an ever increasing number of cases on the list. A case once remitted is entirely in the Board's hands and the Government take no further action. The Government are not on the other hand bound by the Board's report. When the report is presented they form their own judgment on it and any proposals that are placed before the Legislative Assembly are those of the Government, and the Government take responsibility for them.

Clearly much depended on the personnel of the first Tariff Board. The Government and India were extremely fortunate in securing the services of Sir George Rainy, a man of very penetrating brain and extreme thoroughness, Sir Pezonji Ginwala, a man of great independence of thought and rapid appreciation of points, and Professor Kale, who was widely accepted in India for his economic studies and knowledge. The two last resigned their seats on the Legislative Assembly and Council of State to work on the Tariff Board.

The Board was appointed in June, 1923, and the first case remitted to it was an application for protection from the rolled steel industry. The Board was instructed at the same time to take into account the effect of its recommendations, if any, on industries dependent on the use of steel and in particular on those affecting Railways—including the provision of railway wagons and locomotives. This was a large field and a difficult one. The report, which was presented in the following March, covered all rolled steel, such as bars, rails, structural shapes, plates, black and galvanized sheets, tinplate, fabricated steel, such as beams, girders, etc., hoops, strips, nails, wire, steel castings, certain stamped agricultural implements, railway materials, such as steel sleepers, wagons, locomotives, as well as certain items of wrought iron.

Since June, 1923, the Tariff Board has dealt with many articles other than rolled steel, but I can probably illustrate the working of the Board best by following through the history of steel, both for its own interest and because it illustrates admirably many features of the work of the Board. None who are connected with the steel industry need to be reminded how chaotic were the conditions in that industry in 1923 and 1924. The potential productive capacity of the steel works of the world was far in excess of world demand and trading conditions were disorganised by the constant and catastrophic changes in the exchange values of various Continental currencies.

These extremely difficult conditions caught the Steel Industry in India at an unfortunate moment. As a result of the great courage and enterprise of the Tata firm large iron deposits in India had been opened, a new town built in the jungle, and the manufacture of steel had been commenced when the War broke out. This industry had proved its value during the War and large extensions with more modern machinery and better lay-out were commenced at the first opportunity. These had not been completed by the middle of 1923, so that the Company was unable to derive commercial benefit from them, and had, at the same time, to contend with a rapidly falling market. In 1921 the production of finished steel in these works was 125,871 tons. It was anticipated that with the completion of the greater extensions the output would rise to 422,000 tons a year. Other interests were also contemplating the manufacture of steel in India on a large scale but their plans were not so far forward and they were able to defer action whilst watching events. Although there were many features connected with the Tata Steel Company, which attracted public criticism, yet there is no doubt that it was a mighty industrial enterprise which Indian opinion rightly and naturally regarded with much pride.

The industry applied for a general protective duty of 33½ per cent *ad valorem* on all its products. The Tariff Board rapidly found that the three conditions precedent to the grant of protection were satisfied by the rolled steel industry, but the determination of rates which would be "adequate but not excessive" was only reached after much very laborious investigation. This investigation covered the analysis of existing and a forecast of future works cost of the different main products, the calculation of overhead charges based on probable output and estimated replacement cost of the works at current prices and provision for a return on the ordinary capital of 8 per cent. when all economies in manufacture had been effected and full out-turn had been reached. This last would necessarily take some years to achieve. The Board then estimated the effect of its conclusions on the subsidiary industries of engineering, tinplate, wire, agricultural implements, wagons, locomotives, steel castings and enameled hollow ware. They rejected the claims of the locomotive steel castings and enameled hollow ware industries for protection, and in regard to the others recommended varying rates of duties, or, in the case of railway material,

assistance by way of bounties, with the express object, in the general interests of the country as a whole, of keeping down the capital cost of railway construction, railway renewals and transport generally. They thus finally arrived at a coherent, interlocked set of proposals for protective duties and bounties on a wide range of steel goods, each duty or bounty adjusted to the costs of the particular article or group of articles. Finally they estimated the probable additional burden that their proposals would place on the country as a whole, and how they would probably be distributed between different sections of the community. Their results were presented in a report, remarkable for its clarity, the closeness of its argument and the presentation and marshalling of the facts and figures. It was alive with interest as an economic study of an industry undertaken in connection with immediate industrial problems. This first report went far to establish the reputation and confidence which the Tariff Board has since enjoyed in India.

It had notable political results. A General Election had taken place in the autumn of 1923, wherein the Swarajists had for the first time stood for election. They formed a strong section of the new Assembly of 1924, and in its opening session had seriously considered declining to serve on any special Committees of the House. The Tariff Board report was received in March, 1924, too late for consideration in that session. The matter was urgent. A special session was called for May to deal solely with the steel report, which raised a live economic issue, wherein the facts had been thoroughly sifted, analysed and definite proposals made. The session was well attended, and all sections of the House took part in the debates and in the work on Committees. This report of the Tariff Board brought the debate from a discussion of abstract economic theory to the consideration of actual facts. Divisions of opinion based on economic interest and not on political association manifested themselves, and at the stage for consideration of the report the Select Committee, the House, voting against the Government, rejected that section of the proposals which would place protective duties on certain agricultural implements. Except for that, the proposals of the Tariff Board, which the Government had accepted in toto, were passed and embodied in legislation.

Had the Tariff Board been fully endowed with the gift of prophecy the method adopted by it for calculating the various duties, at the difference between the works costs and overhead, after all economies had been effected and full output attained, and the prices at which imported articles would be landed free of duty, would have been perfect. But, then, had its members possessed such prescience they would, in all probability, have been so busily engaged in their own interests as not to have been available to serve on a Government commission. They were, however, conscious of this frailty which they shared with the rest of mankind—inability to be perfect prophets—and tacked on to their scheme two proposals which suggested that the Government and the

Assembly might soon hear again of the woes of the Steel Industry. The construction of the new works was still in progress whilst the enquiry was being conducted and would not be finished for some two years. Conditions were thus changing rapidly in the industry itself, and the Tariff Board advised that, whilst the continuance of protection should be promised, the whole scale of duties should be subject to revision at the end of three years. That at any rate was then three years off. Their other proposal concerned their forecast of the probable course of world prices of steel. Here they boldly hedged, by saying that world prices of steel were at that moment so unstable that, if, during the three years, they changed to such a degree as to render ineffective the protection it was proposed to give, the rates of duty should again be reconsidered. Three months sufficed to show the wisdom of their caution and to enable critics to emphasize the fact that once a country is entangled in the coils of Protection, there is no escape from an ever rising wall of duties.

But those summer months of 1924 were desperate ones for most steel manufacturers. Continental prices had fallen at cataclysmic pace, and in October 1924 Continental steel bars were being landed in India at 37 Rs. a ton below the figure on which the Board had based its recommendation for a protective duty of Rs. 40 a ton. The fall in price had wiped out practically the whole of the duty which had just been imposed as adequate protection. In these circumstances the Board advised increases of duty, which would nearly double the new rates. This would have meant that rates which, calculated ad valorem, ranged, when imposed, from about 30 per cent. to 15 per cent., would in some cases have approached 70 per cent. ad valorem on the new landed cost. Imports were coming in freely, bringing unexpected revenue and the Government preferred to leave the rates of duty unaltered and give the additional assistance required by bounties on all steel produced. The Assembly accepted the Government proposal.

At the end of the three years the Tariff Board once more made a full enquiry into the steel industry and again presented an exhaustive, closely argued report, in the manner in which it had done in the first instance. It found that production of finished steel had been increased to 380,000 tons in 1926-1927, works costs and overhead had been reduced in the three years interval by about 30 per cent. in each case, and that the Company was in every way in a much stronger position. Costs in the old mills originally built were still high, but further additions in order to balance the output of various parts of the works were needed. If these were completed the output should within 7 years probably approach 600,000 tons of finished steel a year. They found that protection was still needed, but that many of the rates at which it should be given should be substantially reduced and that the bounties should cease entirely. This would mean that for most rolled steel products the price to the consumer should be about Rs. 50—which is £3 15s.—a ton less than it was when the protective duties were first imposed in 1924. They recommended, for purely

economic reasons, that for certain articles the protective duties should be split into two parts—a basic duty applicable to any imported steel protected, and an additional duty if the steel were imported from countries other than the United Kingdom. The whole scheme was to be in force for seven years and only the additional duties were to be liable to alteration during that period in case they proved ineffective. One sample will suffice. The basic duty on steel bars—i.e., the duty on British made bars—is to be Rs. 26 (or 39/-) a ton and on foreign steel bars Rs. 37 (or 55/6) a ton. These proposals have been accepted by the Assembly and passed into law.

By the protection, which has so far been accorded it, a most important industry has been maintained and established during a most difficult period, considerable economies in the cost of production have been attained, reduction in the duties originally given has been secured, and at the same time an undue burden has not been laid upon the vital interests of the country—such as the Railways—and on the general consumer. The demand in India for these classes of steel goods has continued to expand. In 1912 the total imports of articles of rolled steel, which later were protected, just exceeded 1,000,000 tons, of which nearly half—444,000 tons—were rails. In 1925-26 imports were still 950,000 tons, and local production—a new feature since 1912—had supplied another 320,000 tons. Out of this total of 1½ million tons, rails accounted for a little over one quarter. With the lower prices now prevailing, it is probable that the demand will still further expand.

This summary of the events in connection with steel illustrates fully the procedure followed in giving effect to the recommendations of the Fiscal Commission, that the policy of protection be applied with discrimination both in the selection of industries for protection and in the degree of protection afforded.

It shows the four stages which must be passed through before an industry receives protection:—

- (1) Application to Government.
- (2) Enquiry, mostly in public, and report by the Tariff Board.
- (3) Publication of the Tariff Board report and of the conclusions of Government thereon.
- (4) Debates in both Houses, the Legislative Assembly and the Council of State.

This account of the steel investigations also shows instances of:—

- (1) The Tariff Board advising that protection should not be given.
- (2) The Tariff Board advising the grant of protection at particular rates, and its proposals being adopted by the Government and the Legislature.
- (3) The Government modifying the proposals of the Tariff Board and the Legislature accepting the Government proposal.
- (4) The Legislature rejecting, and the Government acquiescing therein,

a proposal for protection recommended by the Tariff Board and put forward by Government.

The facts connected with each industry, into whose application enquiry is ordered, are thus collected and marshalled, with issues framed, recommendations made, and a statement of the probable results prepared, before the Government and the Legislature are asked to form decisions thereon. In other words, when that stage is reached, the members of the Legislature and the general public are in possession of the results of a recent purely objective economic enquiry into the industry in question. The debates these reports give rise to are thus real and to the point. And it is a noticeable fact, that except in regard to those agricultural implements, the Legislature have always endorsed the conclusions of Government even when, as has sometimes happened, those have involved modification of the recommendations of the Tariff Board.

In cases in which the Government agree with the Tariff Board in rejecting a proposal completely, or in which the Government disagreeing with the Tariff Board consider no action advisable, the same procedure up to publication of the Government's conclusions is followed. It is then open to any member of the House, if he be dissatisfied with the result, to table a resolution for discussion.

The Tariff Board is under no obligation to advise assistance to industry merely by an enhancement of duties. It is very rightly careful in recommending bounties, owing to the difficulties of administration frequently inherent in them and owing to a consideration of the general financial obligations of the State. But it makes such recommendations which, as a result of its full enquiry, it deems most practical and appropriate in each case.

These may involve the reduction or cancellation of existing revenue duties on imported materials essential for an industry, such as on spelter, sulphur, rubber, tin or cotton mill stores. Or they may involve different treatment for different branches of an industry. Thus, in regard to paper the Tariff Board found that a case did exist for the protection of the manufacture of paper from bamboo, but not for that from mechanical wood pulp. In cement it recommended legislation the enforcement of which would be conditional on certain prior action by the industry itself. Instances have been given in which the Tariff Board found that no case for protection had been made out. The same conclusion was reached by it in its enquiries into magnesium chloride, galvanized hardware, and coal.

The Tariff Board has already enquired into and reported upon a variety of industries in addition to those covered by steel. Its list includes coal, cotton yarn and textiles, paper, cement, printers' ink, ply wood, galvanized hardware and enamelled hollow-ware, and it is enquiring into the match industry. Where protective duties are ultimately imposed they are shewn under a special part of the Indian Customs Tariff Schedule, and that part now covers nearly fifty items, mostly connected with steel.

The reports of the Tariff Board, however, serve a purpose quite distinct from that for which they were primarily conceived. In several cases those actually engaged in the industry under enquiry have stated that the investigations by the Tariff Board have attracted their attention to important aspects of their industry which they were overlooking, and the reports taken as a whole form a most valuable mine of information on Indian industries. They deal with the actual facts of modern industry, and shew cases in which the difficulties which have arisen in the industry have been due to over-production, to wrong location or to changing circumstances in India. They also repeatedly shew how illusory are the prospects of success, when based solely or mainly on the assumption that one industry situated in one locality can serve all the requirements of India, and can reasonably expect to secure all the trade in an article shewn by the totals in the import returns. India is too large for that. The imposition of duties, sufficient to render that possible in the parts most remote from the location of the industry, would result in the imposition of burdens on the country out of all proportion to the advantages likely to accrue. These reports, based on detailed investigations into particular industries, supplement in a peculiar manner general surveys of industrial possibilities. Such general surveys of economic possibilities have their own usefulness, but their utility is greatly enhanced when a series of reports on industry based on recent actual facts are also available.

The procedure of the Tariff Board may be criticised as slow and laborious, but none will, I think, contest the correctness of the general proposition that a Legislature should not be asked to assist an industry without being fully informed of its condition and necessities. That general proposition is of peculiar importance in India, where the economic interests of different parts of the country vary so greatly, that, without a clear statement of the facts based on a detailed investigation into an industry, it is extremely difficult for the members of the Legislature and for the people in other parts of India to grasp the practical points at issue. The advantages which result from this procedure have been repeatedly shewn in the standard reached in the debates in the Legislature on the various definite proposals for protection, and are generally apparent in the regard in which the Tariff Board is held in India. The fact that each case is discussed fully on its merits, with full appreciation of the implications involved, serves to emphasize in regard to each industry that the privilege of receiving State assistance also carries with it the obligation of attaining efficiency as soon as possible. Point is given to this charge by the knowledge that the enquiry will be reopened at a fixed future date not very remote. The encouragement of industries in India, the development thereby of its resources, and the opening out of new avenues of employment, are legitimate and praiseworthy objectives, but in cases where, to achieve that end, State-aid has to be given in the form of protective duties, it is right to strive to ensure that such aid is strictly adapted to the need and is given by

the Legislature in full understanding of the facts. It is the task of the Tariff Board to provide impartially and clearly the material on which such decisions can be based.

DISCUSSION.

Sir William Larke, K.B.E. (Director, National Federation of Iron and Steel Manufacturers), in opening the discussion, said he was fully conscious of the fact that he did not deserve the prominence he occupied in opening the debate but would willingly do so out of regard to his friend, the lecturer. He hoped that the paper would find the widest possible circulation throughout the Dominions and the Empire. It was, in his opinion, an invaluable record of the operations of a Tariff Board which might be taken as a model throughout the world. He thought that the Fiscal Commission, of which the Chairman was a distinguished member, in making their recommendations might have wondered whether they were in fact recommending a counsel of perfection. The desiderata to be complied with before any industry was likely to secure protective duties—"That the industry possessed natural advantages, that without the help of protection it is not likely to develop at all or not so rapidly as is desirable, and that it will eventually be able to face world competition without protection"—might well give rise to a doubt as to whether it was possible to comply with all those conditions. He was particularly interested in the steel industry of this country, and had watched the application of the steel industry to the Tariff Board in India on both occasions it had been before them. He could unhesitatingly say that the Tariff Board examined the conditions of the steel industry so critically and in such detail that they were quite justified in their conclusions that the Indian steel industry complied with the desiderata he had just mentioned. The attitude of the British industry to those applications was dictated, it might be said naturally, by self-interest, but he hoped by self-interest governed by some considerations of a far-sighted statesmanship. Their attitude was, first of all, that India possessed natural resources on which to base an iron and steel industry, and that the iron and steel industry of India was an established fact and quite rightly looked forward to a prosperous future development; secondly if the claims of that industry to a measure of protection came before the Tariff Board—and in that case in his view protective duties did not involve a doctrine but were simply an expedient which might be applied in varying degrees or abolished at varying periods without there being any inconsistency in such changes—it was quite natural in their view that the Tariff Board and the Government of India should consider the application of those duties. The attitude of the iron and steel industry in this country was that if the Tariff Board examined the conditions, having regard to the economic needs of India, it was up to the industry in this country to assist the Tariff Board in every possible way by giving such information as it possessed with regard to European costs and European conditions of production. That the industry here was able to do, and had the opportunity of furnishing such information to the technical adviser of the Tariff Board, who received what information he desired. The British industry disclosed to him costs that the individual Firms would not disclose to each other, the reason being that the manufacturers here wished the Indian Tariff Board to have that information so that they might reach a proper conclusion having regard to the economic needs of India. They felt that that was the best method of ensuring that protective duties were employed in a statesmanlike way. The assistance

which the British industry was able to give he thought was justified. When it came to the point of the application of differential duties which appeared to favour the United Kingdom they had no delusions about them; they did not consider them a preference; they were, in fact, a demonstration of the statesmanlike manner in which the Tariff Board applied themselves to the application of those duties, because the differential duties in favour of British products were based entirely on the difference in conditions in Britain and on the Continent. It was hoped that those differential duties might later grow to conscious differentiation in favour of the United Kingdom, but that was not the case to-day. The British iron and steel industry's attitude towards the industries throughout the Empire was one of co-operation. They were convinced that the steel industry in the Mother Country should co-operate in the development of iron and steel industries throughout the Empire where the Dominions possessed the necessary resources on which to base an effective iron and steel industry. Such industries might be expected to assist in the industrial development of the Dominions which would increase their wealth-producing capacity and so increase the volume of inter-imperial trade. They therefore benefited by such expansion. There was nothing particularly unselfish perhaps in their policy, but at least it had the virtue that it was free from parochialism and would assist the development of the economic prosperity of the Empire as a whole. With regard to differential duties, they were greater than the example the lecturer had given. There was a difference of 16.6d. per ton in favour of Great Britain in the case of girders and joists as compared with the Continent, and that difference without any detriment to India had encouraged British exports to India of those particular products as against Continental exports, and would give Great Britain every opportunity of establishing still closer co-operation. He had been filled with admiration at the way in which the Tariff Board had conducted their labours, and still more with the remarkable case that was produced by the applicants and the detail which they presented to the Board, showing their costs actual and potential and the possibilities of the future. Anyone who studied the proceedings before the Tariff Board would receive an education in industrial economics in a country that had developed industrially very rapidly. He hoped that the lecture would produce a very interesting discussion, and that it would be widely circulated, and that efforts at co-operation with the Indian industry might ultimately result in the increasing development of India, to the mutual benefit of Indian and British producers through the continual expansion of Indian trade.

SIR ATUL C. CHATTERJEE, K.C.I.E. (High Commissioner for India) said he could not help attending that evening to listen to a lecture by his old friend and colleague, Sir David Chadwick, on a subject which was naturally of extreme interest to himself. He had no doubt the audience would agree with Sir William Larke in expressing admiration for the lucid manner in which the lecturer had given an exposition of what had been done by the Tariff Board in India and the principles which had guided the Board and the Government of India in dealing with the questions before them. On a previous occasion in the Hall of the Society he had taken credit for the Government of India for the success which had attended the policy that was laid down by the Commission of which the Chairman was one of the most important members. That was the policy of discriminating protection. As the lecturer had pointed out, there were many doubts when that policy was adopted whether it would be possible ever to reach a stage at which, once protection had been given on a certain scale, it could possibly be reduced. Apparently the steel industry

in India, which was assisted by the recommendations of the Tariff Board, had proved that the recommendations had really been carried into effect, and it was to be hoped that similar success would attend the policy in regard to other commodities which were now being manufactured in India. He was in entire agreement with Sir William Larke when he said that the policy should be adapted to the peculiar circumstances of the country and of the moment. He did not think it was possible to adopt any fixed principle in those matters at all. He was very glad also to listen to what Sir William Larke had to say in respect to the duties which had been imposed in India on the British industry. He had very close contact with British industry in many respects and he wished it every possible success. The preference, however, was given in the interest of the Indian consumers and not in the interest of the British industry, and it was necessary to emphasise that point once again. The lecturer had pointed out very clearly many safeguards which had to be adopted in India in order that the tariff policy which was adopted might not lead to very serious difficulties. It was true that the process was a slow and cumbrous one, but he thought it would be admitted that not only the Government of India, but the Legislative Assembly, had responded to their responsibility in that respect. The only instance the lecturer had given of the Legislative Assembly departing from the Government's recommendations was to the credit of the Legislative Assembly. He hoped that when people talked about the responsibility of the Legislative Assembly, the economic and social legislation that had been passed in India during the last few years would be taken into account. He did not think that the Assembly could for a moment be accused of having neglected any prominent or even any minor interest in their decisions. He had not always seen eye to eye with the Assembly, but it was necessary to bear those facts in mind.

MR. N. SANYAL said there were certain points which arose in his mind as a student of economics which he wanted to place before the meeting. Evidently the recommendations of the Tariff Board were leading India to a position in which foreign capital was tending to be more and more attracted for investment in Indian industries. It had been proved of late that the Swedish match industry was trying to open up factories in India, and Japan was also making attempts to establish factories there. Similar attempts were also to be noticed in connection with this country. When the Tariff Board made its recommendations and the Fiscal Commission published its very interesting report, he was afraid they could not foresee that possibility of increased investment of foreign capital in the country. While it was no doubt true that in the interest of the development of Indian industries, which had been the aim and object of the Tariff Board and Fiscal Commission, there must be a certain amount of foreign capital invested in India, he should like to know whether there was any practical method by which the amount of such foreign investment could be brought under control. The Government of India had appointed the "External Capital Committee" probably with that end in view, but no effective method could be suggested by them.

MR. H. A. F. LINDSAY, C.I.E., C.B.E. (Indian Trade Commissioner) said he was sure the lecturer would be able to satisfy the last speaker, but he should like to draw attention to one point in the situation, namely, the relative cheapness of local and British capital for industrial development in India, and remind the speaker that the serious difficulty and danger in the Indian industrial position was not, as in England, unemployment of the lower classes but unemployment of

the middle classes, and that the industrial development of India whether with foreign or British capital would surely help to remedy that situation and to supply employment where it did not exist at present. On the question of unemployment, it was necessary to be careful in India that the industrial manufactures and agricultural industries developed on parallel lines and in equilibrium. Every State must aim at such a development of its industries and of its agriculture that, as far as possible, an equilibrium was maintained between the two. That point was brought out very clearly, especially by Dr. Hyder, at the World Economic Conference at Geneva last year. He thought the French delegates made a point that they must protect their agricultural industry because it was in danger of being submerged by the manufacturing industries which were developing more rapidly than the agricultural, and Dr. Hyder was able, with a great deal of common sense, to show that that desire for equilibrium was evinced by India in the direction of a stimulus to her manufacturing industries so that they should not be swamped by agricultural industries. He noticed not very long ago that his friend, Sirdar Jogendra Singh, Minister of Agriculture in the Punjab, took a very wise step forward which, so far as he had seen, had not been imitated in other countries, and that was to form in the Punjab a Joint Agricultural and Industrial Association, an Association in which agriculturists and manufacturers were equally represented. By that means it was hoped that a common policy would be evolved in which the interests of both those great sides of the country's industries would be developed on parallel and balanced lines.

PANDIT AHLUVALIA GOPALJI said that the industries of India needed protection from the exploitation of foreign capitalists. If the Tariff Board acted in conformity with Indian national interests, they would win the confidence of the country.

MR. J. E. WOOLACOTT said that there was a distinct desire on the part of all thinking men in this country to assist in the industrial development of India. With regard to foreign capital, it had made India industrially what she was to-day and, in fact, made her industries possible. The Chairman and he had had many discussions on discriminating protection in Simla and Delhi, and he was surprised that the Tariff Board, which was the outcome of the recommendations of the Commission of which the Chairman was so distinguished a member, accomplished the miracle of reducing protection once it was established.

THE CHAIRMAN said the lecturer had described what the Tariff Board had done, and he would just like to refer to what India had not done as evidenced by the contrast of conditions in Europe to-day. He was on the World Economic Conference at Geneva in May and he was struck by the extraordinary complication and embarrassment in Europe through the haphazard manner in which duties were imposed, sometimes for political reasons and sometimes almost hysterically on supposed economic grounds, taken off and re-imposed with such extraordinary rapidity that no sound commerce was possible. The lecturer had shown that under the present Indian system such an unsatisfactory state of affairs could not occur in India. The appeal in the first instance must be to economic law, and the Tariff Board was outside party or political considerations in the Assembly. Another defect in Europe disclosed at the Geneva Conference was called the *tarif de combat*, the constant rattling of economic sabres, putting on high duties quite irrespective of economic conditions, in order that there might be something to bargain with when other countries were approached. That was another evil which the Indian

system had escaped. The lecturer was almost apologetic when he said that the tariff policy of India was rather slow and cumbersome. That would appear to be one of its great merits. It meant that there could not be constant and factious changes of duties, and therefore commercial men could trade with some security and be certain that when they booked an order the profit would not be taken away by sudden changes of duty before the goods were shipped. Another danger which he thought the Fiscal Commission could take credit to itself for avoiding was the baneful doctrine of self-sufficiency, the theory that a country must produce everything it wanted for itself and at any cost to its nationals. That was not the policy in India. It had been attempted in other countries, but it must invariably fail. India especially could not attempt such a policy. India had natural facilities to a wonderful degree for producing goods in larger quantities than she herself could possibly consume—jute, tea, manganese, ground nuts, cotton, etc. India was endeavouring to use up more and more of her own cotton, but was also making great efforts to produce more and more of the raw material and of a finer quality. Sir William Larke had referred to the great tolerance of the Tariff Board, as to the way it was willing to obtain evidence from everyone, and that had been one of the outstanding features of the Board. It had explored the iron industry not only in India but also in England and the Continent, and it was doing the same with regard to matches. It had always invited evidence from anyone who was willing to give it, and in the cotton enquiry evidence was given by Japan. Lancashire, on the other hand, very wisely considered that a question affecting Indian duties was a question for India herself, and their generous action in not making any agitation to affect the findings of the Tariff Board had done a great deal to bring Lancashire and India very much closer together and to bury past differences. So long as there was a strong Tariff Board as at present, and so long as there was a strong Ministry in India as there was at present, and an Assembly, consisting of diverse elements drawn from all over the country, each able to point out where their own community, their own interest and their own locality were affected, he thought India's tariff policy would continue on the sound lines it had hitherto followed.

THE LECTURER, in replying to the discussion, said he wished to remove one misapprehension which had arisen. The way the Tariff Board went to work amongst themselves was to try and assess the difference between the future cost of production in India and the cost at which goods were likely to be landed, and for the latter it was very material to be able to know what were the costs in the country where the goods had been made and from which they had been exported. Sir William Larke was right in saying that the British manufacturers gave the Tariff Board access to their actual costs which they did not generally publish or tell each other about. He wanted to acknowledge fully the really statesmanlike attitude taken in regard to all the protective questions in India by the National Federation of Steel Manufacturers, and also by the cotton industry, when the question came up. They made no attempt to influence the Tariff Board in any way whatever. He would emphasise that when once a matter was referred to the Tariff Board the policy of the Government of India was to leave the matter with them. The Board called all the evidence they wished and had solely to form their judgment in the best manner they could and from the best sources from which they could obtain information. Those reports were discussed very fully in the Assembly. The Swarajist Party and every other party co-operated with the Government in analysing the reports and forming their decisions upon them. He claimed that so far the work of the Tariff Board had commanded the support of all political parties in

India, not that every decision had been taken unanimously, a thing it would be impossible to obtain in any assembly, but in the divisions would be found Swarajists voting on one side and on the other, not running as a complete political party. In other words, they were making their own decision man by man according to what they felt to be the economic facts of the case. The point was raised as to whether protection would not encourage India in obtaining foreign capital. It did to a great extent, and it was one of the normal results of protection just as another normal result was to increase the cost of the article protected. The question of foreign capital was considered by the Foreign Capital Committee, and they pointed out, as Mr. Lindsay had pointed out, that that capital when it did come helped also to develop the country, and not only brought in a new occupation and a new line of industry, opening up new employment, but, as had happened to many industries, the industry gradually passed into the ownership of the people on the spot through the purchase of shares, and gradually more and more came under their own control. That invariably happened wherever an industry had been started by somebody external under the help of protective duties. With a complete world trust matters were more difficult. How long a world trust could continue in a particular article nobody could say. With regard to the match industry, the subject was at present under enquiry, and he did not know what conclusion the Tariff Board had arrived at, if they had arrived at any.

SIR REGINALD MANT, K.C.I.E., C.S.I. (Chairman of the Indian Section), in proposing a very hearty vote of thanks to the lecturer for his most interesting and inspiring lecture, and to Sir Campbell Rhodes for taking the Chair and contributing to the discussion, said the Chairman shared with himself a certain parental responsibility with regard to the Tariff Board, and he must at times have glowed with parental pride, especially when Mr. Woolacott confessed himself converted. The lecturer had modestly not referred to the assistance which the Tariff Board derived from the Department with which the lecturer was associated. The department had nothing to do with the enquiry when once they had handed it over to the Tariff Board, but they had in the first instance to select subjects for enquiry and remit them to the Tariff Board, and they had afterwards to form their conclusions on the reports and present a policy to the Assembly and persuade the Assembly to carry it out. The fact that in only one minor instance did the Assembly reject the proposals of the Government showed how ably they were prepared and presented to the Assembly by the Department to which the lecturer was attached. Unfortunately Sir David had had to sever his connection with India, and India's loss he hoped would be the Empire's gain through his present connection with the Imperial Economic Committee.

The meeting then terminated.

CORRESPONDENCE.

ROAD TRAFFIC PROBLEMS OF THE PEDESTRIAN.

"It would be a profound blessing if Colonel O'Gorman's admirable suggestions could be enforced on pedestrians." So writes Prof. L. W. Lyde on December 16th ostensibly in support of my "Pedestrian's code of Road Manners."

I say ostensibly, because the Professor shows a certain roguishness by importing into my admirable suggestions precisely that which I studiously excluded, namely,

that which is warranted to make them odious to Britishers, viz., *compulsory* manners.

The plea against any enforcement was two-fold. I said :

- (1) That lives could be saved if we instilled into people, *by education*, considerate pedestrian manners.
- (2) That "such a code *should not* convey that lapses are punishable in any way" (p. 41).

The paper then gave reasons for *not* enforcing the suggestions and enlarged on the various methods of instilling the code by education (p. 42).

If therefore Professor Lyde thinks he is supporting my thesis by asking for enforcement of my suggestions, he must have read my paper hurriedly. Alas, he was worse than hurried when he came to the question of vehicle speeds. I do not know how else to suggest without offence that he is either uninformed on London traffic problems, or suffers from a "complex" on speed or is, what all humans may be, just simply wrong; wrong, when he reprobates drivers for "being sufficiently foolish, selfish and reckless to drive over 20 m.p.h. in London;" mistaken, when he asks "how many have been convicted for this?" (because the question is irrelevant, convictions being a measure of police activity and no measure of drivers); amazing, when he suggests a means for elucidating my "perfectly worthless" statistics by which I "ruin what might be a perfectly sound case"; and inaccurate when he states that my "percentages are not real percentages at all because they ignore the totals under each heading" (the totals are actually given). Professor Lyde conveys that, given a correct estimate of the car drivers who, in London, in 1926, exceeded 20 m.p.h., he can say what their percentage of killing was. Let him try! The approximate number of car, van and motor cycle drivers who, in London, in 1926, exceeded 20 m.p.h. (not once but many times) is over 200,000. The number of fatalities in that year, in London, at that speed and over was 45. When he *has* tried he will find that the answer is a "lemon." It means nothing.

My figures, which he decries as "worthless"—the percentages he calls "unreal"—are on the other hand illuminating. They are, moreover, not mine, but those of the "*Report on Street Accidents in Greater London*," March 1927, signed by Sir Henry Maybury and issued by the Transport Ministry. They seem to clash with certain preconceived ideas of the Professor; thus they show that of the total road fatalities in 1926 in London, no less than 56 per cent., a majority, occurred when the vehicle speeds were under ten miles an hour! They show that the astonishing figure of 78 per cent., a very large majority, of the fatalities occurred when the speeds were under 15 m. p.h., and, still more worthy of note, because the cumulative evidence may help towards life saving, by substituting thought for prejudice, only a small percentage (4.5 per cent.) of fatalities are ascribed to speeds of 20 m.p.h. and over! Police measures of car speeds are not generally considered to be too low, but in my paper restraint was used in drawing conclusions from these measures. I deduced from the statistics that "a plea against improving traffic flow (in Greater London) on the ground that greater vehicle speeds are necessarily associated with more frequent fatalities fails to find support" in these statistics.

I did *not* deduce that the faster one went the less one was liable to accident, nor did Colonel Pickard think so when he indulged in the gentle art of pulling the lecturer's leg. It is possible that these singular percentages mean that accidents occur dominantly in places where there are congestions of traffic, pedestrian or other. That is the surmise I made, and if congestions introduce a dominant risk, these statistics are a justification for my paper devoted to the cure of congestions.

Professor Lyde found that I was "scarcely relevant and far from convincing because I refused to be caught arguing against a subtle platitude thus:—

"Excessive speeds, having regard to all the circumstances of the case, are by far the most outstanding causes of accidents."

Now modify the adjectives, and the platitude stands revealed:—

"Dangerous speeds . . are by far the most dangerous."

Of course they are! We need not even exclude the maniac who preferred to kill at 5 m.p.h. since his mania was one of the "circumstances of the case" which makes 5 m.p.h. dangerous, or, if you prefer it, "excessive."

With reluctance I turn to the last point: that my statement about dogs, in the absence of percentages, is worthless and reckless. I extract my entire allusion to dogs in the paper:—

"An impediment to the introduction of increased safety measures among walkers is their sense of injured innocence. This may be natural in view of their fragility in traffic, but it is not warranted. Dogs who play in the street are equally fragile, feel equally innocent and are equally mistaken."

My point is that pedestrians or dogs may (and do) cause accidents between vehicles or to vehicles and drivers who swerve to avoid them, the *causa causans* remaining unaware of his effect.

"Drivers," I continue, "are far more often compelled to dangerous passes by pedestrians than by dogs."

That is the entire statement. It rouses the Professor's ire. He brandishes his emphasis. How dare I omit the total of pedestrians abroad that Sabbath day—and their relation to the number of dogs ("not on the lead")? These last four words show with what meticulous precision such statements should be made. Had I but given the required ratio, my remark, though still true, would not have been "worthless and reckless!" My godfather!

MERVYN O'GORMAN.

P.S.—In despite of our mainly verbal differences, I thank Professor Lyde for his letter and feel that we are of one mind in wishing to save pedestrians in their very grave difficulties.

NOTES ON BOOKS.

COLLECTED PHYSICAL PAPERS. By Sir Jagadis Chunder Bose, M.A., D.Sc., LL.D., F.R.S., C.S.I., C.I.E., Founder and Director, Bose Research Institute, Calcutta. London: Longmans, Green & Co., Ltd. 10s. net.

Sir Jagadis Chunder Bose occupies a position which is peculiar, and in some respects unique, amongst scientific investigators. To the outside world he is probably best known in connection with his famous "crescograph"—the instrument by the aid of which the growth of plants can be actually seen taking place. If one were asked to characterize his researches shortly, one might say that he has concerned himself mainly with the behaviour of matter, both living and non-living, when exposed to the influence of external shocks or stimuli. Indeed, the crescograph itself originated rather on these lines: the real object of investigation was not so much the rate of growth, but the manner in which that rate was influenced by changes in the environment.

The stimuli which have been studied have been very varied in kind; but in the present volume of reprints we are concerned mainly with light and with those longer radiations which are commonly described roughly as "electric waves."

The crescograph papers are, however, also included. By the original mechanical crescograph (1917) the growth was magnified ten thousand times, by means of two levers each magnifying a hundred times; and it was possible to measure the amount by which the plant grew during a period of less than one second. In one specific instance the growth per second was found to be about the thousandth part of a millimetre. With the magnetic crescograph, however, invented in 1925, we enter on a totally different field, for the growth is magnified by the almost incredible figure of fifty million. With this instrument, in the case of the flower-bud of the *Crinum* lily, the indicating spot of light moved three yards in five seconds; and the author states that this enables us to register and measure the amount of growth which takes place in this plant during a time-interval lasting less than $1/500$ th of a second.

It will be remembered that these sensational announcements were not accepted without criticism by the scientific world. With apparatus so inconceivably delicate, it was clear that one had to be satisfied that the observed movement was not due to causes other than the plant's own growth; and it is notorious that Bose's claims have had to run the gauntlet of an exceptionally severe examination. This, however, is quite as it should be; and the whole incident may well serve as an object-lesson to those who take pleasure in making the most of the difficulties which have sometimes been experienced by the genuine discoverer in obtaining a fair hearing for views which have been considered revolutionary or in some way "unwelcome."

PLANT AUTOGRAPHS AND THEIR REVELATIONS. By Sir Jagadis Chunder Bose.

With Portrait, and 120 illustrations in the Text. London: Longmans, Green and Co., Ltd. 7/6 net.

Sir Jagadis Bose is well known as having given us various volumes on the vital functions of plants, and the present work may be regarded as a matured and elaborated version of his previous teachings; the new features being extended experimentation, abundant illustration, also conjectures or speculations as to theoretical aspects and the hope of practical applications.

As an example of the experimental and demonstrative features which form the staple of the book, we refer to p. 82, where Fig. 47 shows us the parts and workings of the author's "High Magnification Crescograph"; a notable advance on the telescopic system used by the Spanish botanist Cavanilles (see Phipson, *Mysteries of Nature*, Ed. of 1876, p. 137). The Bose crescograph, in the form represented by Fig. 47, gives a record traced on smoked glass by a point, but the growth record on p. 83 was not obtained by cutting a continuous groove in the deposit of soot with a point always in contact, as this would put undue stress on the delicate mechanism. A clockwork device brings the needle-point to gentle contact on the film of soot at regular intervals, for example, 100 or 200 times a second, and these touches denude the glass so as to give a trail of transparent spots indicating both time and the growth characteristics; as also a recession after each quantum of advance. Sir Jagadis expounds this by saying: "The growth process is, therefore, not steady, but like the wavelets of a rising tide."

The record of this wavelet growth, as shown by Fig. 48, is almost beautiful in its sinuous representation of quanta in advance and recession. Magnified representations of the upward or growth phase are shown by Fig. 49; but in this instance there is progressively increasing electric stimulation of the growing plant. Under the highest degree of electric stimulation we see that the growth is reversed, so that there is "actual shortening."

All kinds of stimulation, if exceeding a certain intensity, produce contraction (p. 85), but ether vapour in small doses, gentle warmth, as also mild Hertzian wave action ("wireless") may be mentioned as accelerating growth, Fig. 55 showing the effects of both moderation and excess in Hertzian wave action.

Stimulants, depressants, and the more active agents dispensed by the pharmacist ; as, for example, certain alkaloids, also that cobra venom which Hindu medical men have used for nearly 1,000 years, have been studied by the author in relation to plants (pp. 89-93).

Mere mention of the numerous experimental demonstrations and the many recording devices would involve more space than can usually be allowed for a review ; and, moreover, would be largely futile for lack of details. It may be better to try to show how the diverse habits of mind may be advantaged by reading the book itself. Even a child may understand the leading ideas, such as the author's contention that all "life-reactions" of animals are "foreshadowed in the life of the plant," preface p. vii. The clear and concise diction, with full and appropriate illustration, make the work one well suited for general reading and for inclusion in the municipal libraries of our time, as also in the small domestic library which is now a feature in almost every cottage.

Notwithstanding this suitability for use by the masses, we think we may say that the student of philosophy or metaphysics will most notably and fundamentally extend or mature his views by meditating on the teachings of Sir Jagadis. In the borderland that Barlow strives to explore in his "Connection between Physiology and Intellectual Philosophy," published in 1842 by Pickering, the main argument is approached by a reference to the lowest class in Rudolphi's systemisation of the animal world ; this being the class that Rudolphi taught us to call "crypto-neura, the hidden-nerved." The extremes of this class may, we think, be exemplified by certain abdominal worms on the side of definite animalism, and by sea anemones on the side tending towards vegetablistism, but if the term crypto-neura should come into more general use as a result of the author's endeavours towards a unification of the vegetable and animal kingdoms, nearly all plants may ultimately be included in the class crypto-neura.

On the upward or evolutionary aspect Barlow attempts a physical distinction between the nervous mechanisms incidental to instinct and those incidental to mentality or reason. Barlow also, like Sir Jagadis Bose, emphasises the wide gap between mankind and any animal that may be taken as next below man. Only in man do we find the full powers of mentality or reasoning, putting his reasoning into writing so that other human beings can understand it, proving general or abstract truths by pure or metaphysical reason, and applying the result to the advantage of his fellow-creatures. An example of these conditions as realised by man is to be found in the origin and applications of Euclid's forty-seventh proposition (Book I) ; this outcome of mentality or pure reason having helped in the construction of trigonometrical tables, which tables in their turn have not only aided in the designing of our ships, but have also helped mariners in safely guiding the ships.

Man thus stands paramount and unique at the head of the series of organised or living beings as we find them on earth. Sir Jagadis strikes many notes of admiration and of desire for deeper knowledge, as, for example, on pp. 219, 220 and 97. In another place (p. 61) the author, who gives us his teachings from the East, reminds us that thirty centuries ago his ancestors, speaking from the banks of the Ganges, proclaimed that "they who see but One, in all the changing manifoldness of this Universe, unto them belongs Eternal Truth."

THE PROSPECTIVE DEVELOPMENT OF PERU AS A SHEEP-BREEDING AND WOOL-GROWING COUNTRY. By Aldred F. Barker, M.Sc. Illustrated with Photographs taken by Col. Robert J. Stordy. The University of Leeds.

This Report on the results of the last five years' experimental work which has been carried out at the Peruvian Government Model Farm at Chuquibambilla, Southern Peru, with a view to assisting the development of a large-scale wool-growing industry in Peru, is the outcome of a visit of inspection which the author, who is Professor of Textile Industries at Leeds University, was invited to make by President Leguia in the summer of 1926. The value of the Report, which is very detailed and complete, is enhanced by a large number of admirable and excellently reproduced photographs, taken by Col. Stordy, the Manager of the Government Model Farm, and also by charts and graphs bearing upon the special characteristics of Peruvian sheep and the results of various crosses with other breeds. There are also included at the end of the Report some interesting samples of cloths made from native Peruvian wool, and cloths of similar manufacture made from improved Peruvian wool. These samples, and the comparative photographs illustrating the fleeces of native Peruvian sheep and of various 'crosses,' show very clearly the vast improvement which can be made in the quality and output of Peruvian wool. Professor Barker indeed suggests that the wool-clip of Peru may be quadrupled within a decade.

Professor Barker also mentions the interesting fact that whereas in 1887, when he first came to the Bradford district of Yorkshire, and up to about 1900, wool manufacturers had completely lost, since the development of Australasia, the Cape, and South America as the great wool-growing countries of the world, that close contact with wool-growers which they formerly possessed when they drew their supplies from British sources, a change in this state of affairs set in from the beginning of the 20th century, and wool manufacturers are now increasingly anxious to know as much as possible about the breeds and types of sheep in the various countries from which they obtain supplies of wool for particular purposes.

GENERAL NOTE.

BRITISH INDUSTRIES FAIR (February 20th—March 2nd).—An advance overseas edition of the catalogue of the British Industries Fair, 1928, was issued at the beginning of January, so that it can be in the hands of trade buyers in Europe and America in sufficient time to enable them to visit the Fair after its receipt. Visitors from cities as distant as Johannesburg and Buenos Aires will receive their copies in time to study them on their voyage to England. Copies are also being sent where possible to those buyers who have notified the Department of Overseas Trade of their intention of attending. The advance catalogue contains particulars of the exhibits of 1,125 firms, with an index in nine languages. An accompanying booklet gives a list of the 700 exhibitors in the Birmingham section.

The area occupied by the exhibitors' stands at the White City, Shepherds Bush, will be 250,000 square feet. Almost everything made in Great Britain, apart from the products of the "heavy" industries which exhibit in Birmingham, will be shown.

Taking both sections together, the British Industries Fair will be the largest yet held and nearly twice as large as in 1926.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, JANUARY 16...Brewing, Institute of, at the Charing Cross Station Hotel, Strand, W.C. 7.45 p.m. Annual General Meeting. Mr. James Stewart, "Malting Barleys of 1927."

Geographical Society, at Lowther Lodge, Kensington Gore, S.W. 5 p.m. Mr. G. M. Lees, "The Physical Geography of South-East Arabia."

Victoria Institute, at the Central Hall, Westminster, S.W. 4.30 p.m. Dr. W. Bell Dawson, "The New Testament Era in the Sequence of Prophecy."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Prince D. S. Mirsky, "The Russian Novel after 1880." (Lecture I.)

At University College, Gower Street, W.C. 2 p.m. Prof. M. T. Smiley, "The Greek Epic."

University of London, at the School of Oriental Studies, London Institution, Finsbury Circus, E.C. 5.15 p.m. Mr. I. A. D. Leslie, "Across the North-East Frontier of Burma."

TUESDAY, JANUARY 17...Anthropological Institute, 52, Upper Bedford Place, W.C. 8.30 p.m. Prof. R. Ruggles Gates, "Amerindian Crosses in Canada." Automobile Engineers, Institution of, at the Engineering Club, Wolverhampton. 7.30 p.m. Mr. E. A. Watson, "The Electrical Characteristics of Spark Gap and Sparking Plugs."

Electrical Engineers, Institution of, at the City Hall, Leicester. 6.45 p.m. Messrs. A. H. Law and J. P. Chittenden, "Higher Steam Pressures and their Application to the Steam Turbine."

North-East Coast Institution of Engineers and Shipbuilders, Middlesbrough. 7.30 p.m. Mr. J. Calderwood, "Diesel Engine Drive for Generators and other Auxiliary Machinery on Board Ship."

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Mr. P. R. Coursey, "Dielectrics for Electrical Condensers."

Statistical Society, at the ROYAL SOCIETY OF ARTS, ADELPHI, W.C. 5.15 p.m. Prof. G. W. Daniels, "The Post-War Depression in the Lancashire Cotton Industry."

University of London, at King's College, Strand, W.C. 5 p.m. Dr. J. A. Hewitt, "Integration in the Nervous System." (Lecture I.)

WEDNESDAY, JANUARY 18...Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Mr. H. M. Fletcher, "Architecture of Provincial France."

Civil Engineers, Institution of, Great George Street, S.W. 6.30 p.m. Mr. H. A. Reed, "Appliances for Handling Goods in Ports and Docks." (Vernon-Harcourt Lecture.)

Electrical Engineers, Institution of, at the University, Edmund Street, Birmingham. 7 p.m. Mr. W. Ellerd-Styles, "Large Electric Baking Ovens."

Meteorological Society, 49, Cromwell Road, S.W. 7.30 p.m. Annual General Meeting. (1) Prof. Dr. Hugo Hergesell, "The Observation of Clouds with Special Reference to the Safety of Aviation." (2) Sir Gilbert T. Walker, "World Weather."

Metals, Institute of, at Thomas' Cafe, Swansea. 7 p.m. Mr. W. T. Griffiths, "Some Interesting Properties of Alloys of Nickel."

Microscopical Society, 20, Hanover Square, W. 7.45 p.m. Annual Meeting. Presidential Address by Dr. James A. Murray, F.R.S., "Staining and Structure."

Public Health, Royal Institute of, 37 Russell Square, W.C. 4.30 p.m. Dr. Roland Burrows, "The Medical Practitioner in relation to the Administration of Justice."

University of London, at King's College, Strand, W.C. 5.30 p.m. Mr. Henry Wickham Steed, "The Prelude to the War." (Lecture I.)

At the School of Oriental Studies, London Institution, Finsbury Circus, E.C. 5.15 p.m. Professor B. Karlgren, "The Structure of the Chinese Language—Some Dominant Features in Chinese Sound Evolution."

At University College, Gower Street, W.C. 3 p.m. Signor Camillo Pellizzi, "La Lirica del Paradiso." (Lecture I.)

4 p.m. Professor A. V. Hill, "Muscle." (Lecture I.) 5.30 p.m. Mr. J. H. Helweg, "Georg Brandes." (Lecture I.) 5.30 p.m. Mr. L. Newcombe, "The Central Library for Students."

THURSDAY, JANUARY 19...Aeronautical Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 6.30 p.m. Major W. S. Tucker, D.Sc., "The Problem of Noise in Civil Aircraft and the Possibilities of its Elimination."

Chemical Society, Burlington House, W. 8 p.m. (1) Messrs. G. T. Morgan and H. Burgess, "Cyclo-Telluropolitane." (2) Mr. I. Vogel, "Syntheses of Cyclic Compounds. Part II: Racemic and meso-Ethyl 6,7-diphenylbutane- $\alpha\alpha\delta\delta$ -tetracarboxylate. Synthesis of a Truxinic Acid." (3) Messrs. E. H. Farmer, C. D. Lawrence and J. F. Thorpe, "Properties of Conjugated Compounds. Part IV: The Formation of Isomeric Additive Dibromides from Butadiene."

Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m. Mr. W. Ellerd-Styles, "Large Electric Baking Ovens."

Linnean Society, Burlington House, W. 5 p.m.

Mechanical Engineers, Institution of, at Manchester Mr. Lawford H. Fry, "Some Experimental Results from a Three-Cylinder Compound Locomotive." At Birmingham. Informal Discussion.

Metals, Institute of, at the Engineers' Club, Birmingham, 7 p.m. Mr. T. H. Turner, "Heat Resisting Alloys."

Royal Society, Burlington House, W. 4.30 p.m.

Royal Institution, 21 Albemarle Street, W. 5.15 p.m. Prof. J. F. Thorpe, "Unsaturation of Carbon Compounds."

Tropical Medicine and Hygiene, Royal Society of, 11, Chandos Street, W. 8.15 p.m. Surg.-Commr. D. H. C. Given, R.N., "Some Health Problems of the Singapore Naval Base."

Wireless Technology, Institute of, at the Engineers Club, Coventry Street, W. 7 p.m. Mr. W. H. B. de M. Leathes, "Experiments with Multi-Feed Aerials."

University of London, at King's College, Strand, W.C. 5.30 p.m. Dr. F. W. Rogers Cammell, "The Development of Sex, with special reference to recent work on Birds and Amphibians."

At the London School of Economics, Houghton Street, W.C. 5 p.m. Dr. H. B. Lees-Smith, "The Problem of a Second Chamber."

At University College, Gower Street, W.C. 5 p.m. Dr. R. J. Ludford, "Cytology in Relation to Physiological Processes." (Lecture I.)

5.30 p.m. Prof. J. E. Neale, "The Study of Elizabethan History."

Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Mr. Leigh Ashton, "English Samplers."

FRIDAY, JANUARY 20...British Electrical Development Association, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 7.30 p.m.

Mechanical Engineers, Institution of, Storey's Gate, St. James's Park, S.W. 6 p.m. Fifth Report of the Steam-Nozzles Research Committee.

Medical Officers of Health, Society of, 1, Upper Montague Street, W.C. 5 p.m. Captain Walter Elliot, M.P. and Prof. Dr. R. H. A. Plimmer, "Recent Advances in the Knowledge of Food."

Oil and Colour Chemists' Association, at Milton Hall Deansgate, Manchester. 7.30 p.m. Dr. A. E. Everest and Mr. J. A. Wallwork, "Azolic and other Insoluble Colours."

(Joint Meeting with Society of Dyers and Colourists.) Royal Institution, 21, Albemarle Street, W. 9 p.m. Sir William Bragg, "Photo-Electricity."

University of London, at King's College, Strand, W.C. 5.30 p.m. Maj.-Gen. Sir Frederick Maurice, "The Principle of Mobility."

5.30 p.m. Prof. Karl Young, "The Drama of the Medieval Church."

At University College, Gower Street, W.C. 5 p.m. Mr. C. F. A. Pantin, "Comparative Physiology." (Lecture II.)

SATURDAY, JANUARY 21...Royal Institution, 21, Albemarle Street, W. 3 p.m. Prof. R. W. Chambers, "Some Tudor Biographers."

JOURNAL OF THE ROYAL SOCIETY OF ARTS

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FRIDAY, JANUARY 20th, 1928.

All communications for the Society should be addressed to the Society, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK.

MONDAY, JANUARY 23rd, at 8 p.m. (Cantor Lecture.) ALBERT ERNEST DUNSTAN, D.Sc., F.I.C., F.C.S., "The Scientific Foundation of the Refining of Petroleum." (Lecture II.)

WEDNESDAY, JANUARY 25th, at 8 p.m. (Ordinary Meeting.) H. DE KONINGH, "Enamels, Secular and Ecclesiastic." DONALD WIPPELL, Esq., will preside.

COUNCIL.

A meeting of the Council was held on Monday, January 9th. Present :— Sir Philip Magnus, Bt., in the Chair; Sir Charles H. Armstrong; Lord Askwith, K.C.B., K.C., D.C.L.; Mr. Llewelyn B. Atkinson, M.I.E.E.; Rt. Hon. George N. Barnes, C.H.; Sir Charles Stuart Bayley, G.C.I.E., K.C.S.I.; Mr. Peter MacIntyre Evans, M.A., LL.D.; Rear-Admiral James de Courcy Hamilton, M.V.O.; Major Sir Humphrey Leggett, R.E., D.S.O.; Sir George Sutton, Bt.; Mr. J. Swinburne, F.R.S.; Mr. Carmichael Thomas; Professor J. M. Thomson, F.R.S., and Sir A. T. Wilson, K.C.I.E., C.S.I., C.M.G., D.S.O., with Mr. G. K. Menzies, M.A. (Secretary) and Mr. W. Perry, B.A. (Assistant Secretary).

It was reported that a Ross Cinematograph Projector, half the cost of which had been generously contributed by Sir Charles Parsons, had been installed in the Great Room.

Preliminary consideration was given to the question of the award of the Society's Albert Medal for 1928.

Particulars of the Competition of Industrial Designs were laid on the table.

The Council, Sir Frank Warner and Mr. Carmichael Thomas were appointed Trustees of the Art Congress Studentship.

The following candidates were duly elected Fellows of the Society :—

Armitage, Mrs. Margaret H., Didsbury, Manchester.
 Baker, Henry Gardner, Jun., Alabama, U.S.A.
 Banks, S. J. Egerton, M.I.Mech.E., Richmond, Surrey.
 Bemis, Albert Farwell, Boston, Mass., U.S.A.
 Bonerjee, Karanjaksha, Calcutta, India.
 Franklin, Walter Temple, London.
 Hale, John Howard, R.B.A., London.
 Heaton, Edward Atherton, Pyapon, Burma.
 Hirst, Arthur, London.
 Howard, Francis, London.
 Krailsheimer, Mrs. Audrey, London.
 Lee, Duncan Campbell, LL.B., London.
 Lund, Arthur J., Bingley, Yorks.
 MacDonnell, James Hyndman, London.
 Mahendra Bahadur, Raja Sankara Pratap, Dhen Kanal Feudatory State, Orissa, India.
 Mistri, Manekji Pestonji, Bombay, India.
 Moody, Arthur William, M.D., C.M., Winnipeg, Canada.
 Nicholson, Captain Colin, R.D., R.N.R., London.
 Ramsburg, Charles Joseph, Pittsburgh, Pa., U.S.A.
 Ranken, William Bruce Ellis, R.I., London.
 Roberts, Robert Ellis, M.A., London.
 Robertson, Walter E., Chicago, Illinois, U.S.A.
 Shaw, The Hon. Alexander, M.A., London.
 Spackman, Cyril Saunders, R.B.A., East Croydon, Surrey.
 Srivastava, Amar Nath, Lucknow, India.
 Stobie, Mrs. Lillie, Ryton-on-Tyne.
 Stuart-Bunning, George Harold, O.B.E., J.P., London.
 Waheed, A. F. M. Abdul, M.A., LL.B., London.
 Wilkinson, Willie Horner, Gomersal, Nr. Leeds.

The arrangements for the final part of the session were considered.
 Other formal and financial business was transacted.

COMPETITION OF INDUSTRIAL DESIGNS.

The Society's fifth annual Open Competition of Industrial Designs will be held in June next, when competitions will be held in the following sections :— Architectural Decoration, Textiles, Furniture, Book Production, Pottery and Glass, and Miscellaneous. Over £1,600 will be offered in prizes and scholarships in the various sections.

After the work has been judged a number of selected designs will be exhibited in London, and subsequently at suitable centres in the provinces. In this way they will be brought immediately to the notice of those manufacturers who are likely to be specially interested in them.

It is intended to confer the Society's Diploma on any candidate whose work reaches a very high standard of artistic ability and also shows practical knowledge of the materials and processes of his trade.

A Bureau of Information has been established at the Royal Society of Arts for the registration of the names and addresses of exhibitors who desire to obtain employment as designers. These lists are at the service of manufacturers in search of designers.

A summary of the prizes and scholarships was published in the *Journal* of January 6th, and full particulars can now be obtained on application to the Secretary of the Royal Society of Arts.

DR. MANN JUVENILE LECTURES.

The second of two juvenile lectures on "Flame," given under the Dr. Mann Trust, was delivered on the afternoon of Wednesday, January 11th, by PROFESSOR ARTHUR SMITHELLS, C.M.G., D.Sc., F.R.S., Director of Salters' Institute of Industrial Chemistry.

PROFESSOR HENRY E. ARMSTRONG, F.R.S., presided.

In his second lecture, Professor Smithells, after dealing with the little problems he had asked the children to think over, continued his demonstration of the character of flames. He showed how the bright yellow part of a candle flame arose and, passing to coal-gas, explained how it could best be made to give light when burned in the old flat-flame burner. He then passed to the blow-pipe flame and the oxygen-coal-gas flame, explaining and demonstrating their high temperatures. Alluding to the days when the electric light first came into use and the threat it made to the gas industry, he told the story of how Auer von Welsbach, who was a fellow student in Bunsen's laboratory in 1883, had made the discovery which led in the end to the use of the gas mantle made of thoria and ceria, which had made it possible to get so much more light from gas. With special mantles made for him by the Welsbach Company, he demonstrated the secret of Welsbach's discovery. A high-pressure inverted mantle gas-light, such as is used in Regent Street, was exhibited in action.

Coming to the use of gas for heating, Professor Smithells illustrated the use of the Bunsen flame in its various forms in gas fires, gas-cookers, hot-plates, etc., by examples supplied by the Gas Light and Coke Company.

Referring to the many directions in which we are led by the study of flame, Professor Smithells showed how a flame could be made sensitive to sound, and how it could be made to produce musical notes. He performed a very beautiful experiment with coloured flames produced in the cone-separating apparatus. In conclusion he demonstrated the ways in which flames could be extinguished.

At the end of the lecture an employé of the British Oxygen Company showed the cutting of a half-inch steel plate by an oxygen-coal-gas blowpipe, and slides were exhibited showing, among other things, the cutting of a 1 $\frac{1}{4}$ -inch armour plate by the oxy-acetylene flame.

Professor Smithells expressed his indebtedness to his former assistant at Leeds, Mr. C. G. Durdey, who had come to help him, and to the firms named above and their representatives, who had brought so much to interest his audience.

A vote of thanks to Professor Smithells for his exceedingly interesting lectures was proposed by the Chairman and carried unanimously.

PROCEEDINGS OF THE SOCIETY.

SEVENTH ORDINARY MEETING.

WEDNESDAY, DECEMBER 14TH, 1927.

SIR FRANK BAINES, C.V.O., C.B.E., F.R.I.B.A., in the Chair.

THE CHAIRMAN said it was his pleasant duty to introduce Major R. H. G. Clements, who was to give a lecture on "The Evolution of Modern Road Surfaces." Major Clements, as most of those present doubtless knew, was at the moment a consulting engineer on all matters concerning main highways, bridges, and everything concerned with road transport. He was formerly Divisional Engineer to the Ministry of Transport for the Eastern and Home Counties Division, and he possessed an extensive knowledge and experience of the subject of road transport. He had been the Engineer for various Main Trunk Road Schemes, and had also been Assistant Director on Departmental Committees appointed to consider motor traffic and road legislation. His scientific equipment was reflected by the fact that he had charge of the Roads Experimental Station of the National Physical Laboratory at Teddington. During the war he had seen service with the Royal Engineers on the staff of the Second Army Corps, and he had been with the British Army on the Rhine in charge both of construction and maintenance of roads for military purposes. Major Clements' lectures and papers on subjects connected with roads and bridges, road vehicles, and all allied matters of road transport, must be known to many of those present. He was perfectly convinced that the lecture would be an illuminating one, and he hoped many points would be thrown out of a pleasantly controversial character, which would raise an interesting discussion at the close of the lecture.

The following paper was then read:—

THE EVOLUTION OF MODERN ROAD SURFACES.

By MAJOR R. G. H. CLEMENTS, M.C., M.Inst.C.E.

INTRODUCTION.

The problem of the treatment and the nature and character of the actual running surface of streets and highways which are called upon to sustain in an efficient manner the loading imposed by the intense traffic of to-day, has undergone a very rapid change, and this evolution has indeed been the direct outcome and parallel of the equally phenomenal growth and volume of that traffic itself.

The new problem has emphasised the need for new solutions, demanding the abandonment of old principles and standards, and generally, the evolution of a more precise and scientific basis for its development. Indeed, in very recent years it has virtually called for the creation of new industries, employing materials of diverse character, and constantly taking toll of experiment, research and inventiveness, to seek new means of treatment, to exploit and

adapt fresh material, and generally to aim at a reduction in cost with an increase in efficiency and duration of life.

ENGINEERING FEATURES.

The preliminaries of layout and general construction have been the subject of many informative papers, and the vast amount of new construction and the re-conditioning and adaptation of existing highways undertaken during the last few years, has gradually evolved a solution to most of the engineering problems which are involved, although yet far short of conditions approaching standardisation. Those features, therefore, fall outside the scope of these notes, which is confined to a general review of road surfacing and of the more important factors which have a bearing upon this alone.

SURFACING.

The surface of any highway constitutes the ultimate end of the engineer's labours, for it is upon the perfection or otherwise of this work as a running surface that the quality of his work is judged, and it matters not one iota to the man in the street, or the car, how many inches or feet of material and workmanship lie below that last final surface upon which he moves. All too frequently his criticisms are based solely upon his superficial impression of the part which he sees. It must therefore stand or fall by the test of its fitness as a "permanent way." Its complex character and the difficulties therefore inherent to its mode of construction are seldom understood or allowed for. One may be permitted to add that there is no more difficult problem than to obtain a true and perfect surface in the scientific sense, or to re-assemble again natural or artificially created material to meet this end. Moreover, it can be taken as an axiom that the more near perfection a surface attains, the greater is the emphasis placed upon otherwise minor departures from perfection.

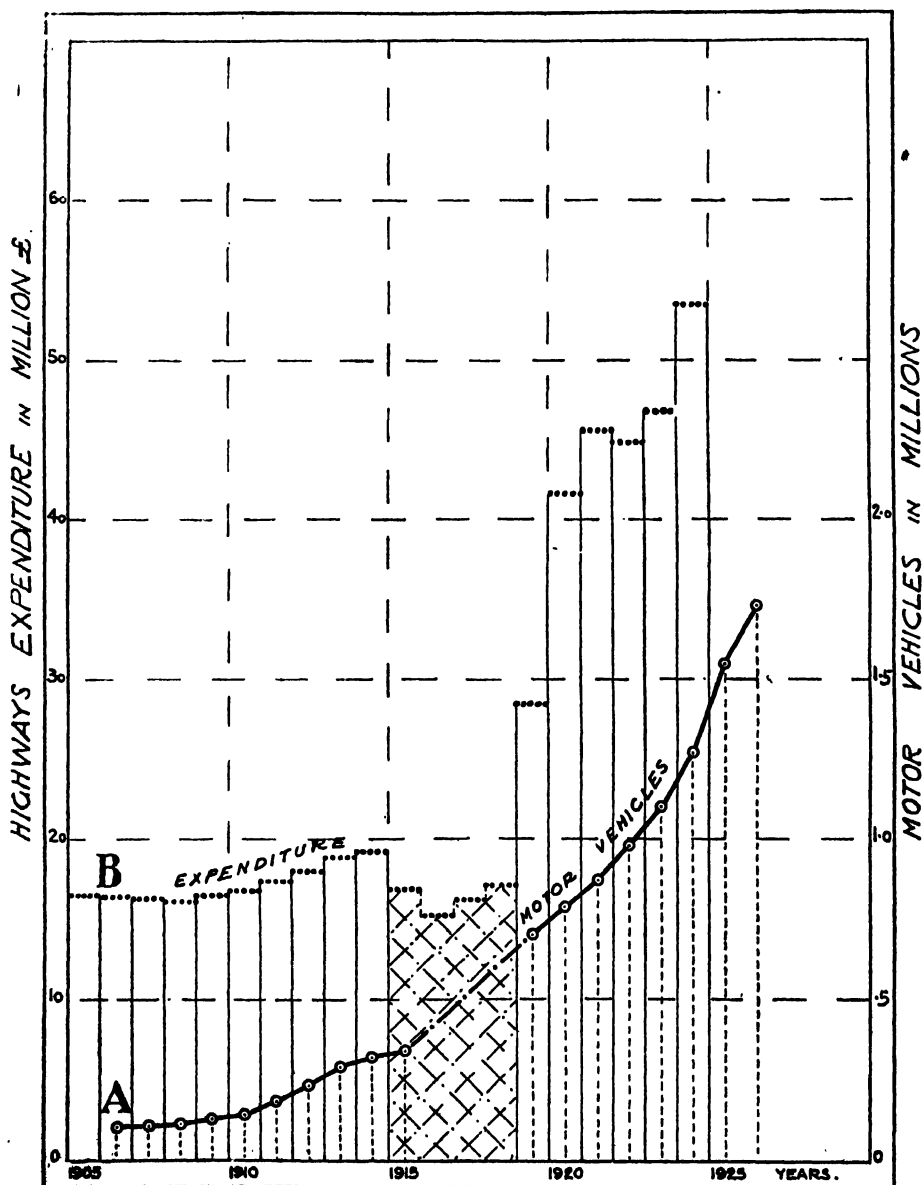
The perfect road surface of to-day should possess, among others, the following characteristics :—

1. *Long Life.* The disturbance caused by repairs or renewals involve a serious economic waste.
2. *Low Maintenance Cost.*
3. *Low Initial Cost.*
4. *Good Surface Texture.* Convenient for the use of all classes of traffic.
5. *Homogeneity.*
6. *Freedom from Distortion.* A surface which remains true to shape under traffic.
7. *Low Ultimate Cost, i.e.,* initial cost divided by years of life.

PRELIMINARY CONSIDERATIONS.

It may be convenient to set out as a preliminary some of the chief considerations which must bear upon a solution of this problem.

The chief factor, and by far the most important, is the traffic loading or density which has almost suddenly come upon all highways. It is too soon yet to predict, and data not are available in sufficient volume on which prediction can safely be made, but there does already exist a series of figures over a term of years which provide an index to future probabilities.



This series is set out in graph form, in which curve A shows the number of mechanically propelled vehicles in each of the years from 1906 to 1926.

These figures, while they indicate a startling increase in numbers, do not by any means go to the root of the matter. Apart from the relative increase in speeds as between horse transport and motor transport, there is a much more significant development in the increased radius of activity of the latter, and corresponding to this, a greater increase in speeds, so that actual numbers alone do not indeed convey the full measure of the "user" of highways.

Again, to take selected instances of traffic loading upon highways. An official census of traffic is recorded periodically—although, unfortunately, these records are not published and cannot, therefore, be utilised as they should to guide design—and it can be shown that road surfaces are being called upon to sustain a daily traffic intensity ranging up to a maximum of 31,000 tons per day and that many instances occur to prove that the volume has increased at certain points by threefold within the three years between the census of 1922 and the census of 1925.

These figures are outside the Metropolitan area, within which still higher values are obtained, and the intensity of loading, assuming uniform distribution across the width of the highway, reaches such exceptionally high figures that already many road-making materials are being stressed very highly indeed.

FINANCE.

This is always an important factor and one which dominates crude engineering conditions more than any other. Despite all that can be done by Central Government Grants, the cost of road construction and surfacing is indeed a heavy obligation and the utmost endeavours are made to secure a low initial cost for the surfacing medium employed.

It is more and more coming to be recognised, however, that the true guide to expenditure is capital outlay taken over a term of years, as to-day most modern materials have got a life value passing out well into double figures, *i.e.*,

$$\text{The true cost} = \frac{\text{Initial cost}}{\text{Years of life}} = \text{Cost per annum of life.}$$

The value of securing the largest possible figure for the denominator is also of importance in another direction, namely, that it postpones or carries forward to the latest date the need of renewal with its vexatious interruption and dislocation of public business and traffic.

The ultimate financial test must be based upon the cost of construction and maintenance per annum divided by the tonnage carried by the road, *i.e.*, the ton unit cost.

MECHANICAL PROBLEM.

The mechanical problem in actual construction is no less tantalising and

intricate, and falls in the main under three types or classes of surface :—

- (A) Reconstruction and combination after breakdown, of crude and naturally occurring materials usually with a binding or cementing agent.
- (B) Block paving systems employing the use of pre-manufactured blocks, *i.e.*, wood, granite, asphalt, rubber, etc.
- (C) The creation of a plastic or mouldable medium which can be spread and laid as a veneer or armouring coat to form the surface.

Types *A*, *B* and *C* exist in their older form as broken stone, water-bound macadam, setts and compressed asphalt respectively. In their modern adaptation their number is legion.

We can conveniently examine the chief characteristics in each group in detail. Each type had its own qualities, and, frankly, its own limitations. Each system possesses features which indicate its advantage or applicability to given local conditions. There is no universal remedy, and the attributes and virtues of each are best recognised and admitted. The most satisfying results are the outcome of a careful appreciation and estimate of the dominant factors, *e.g.*, finance, traffic, gradients, topography, urban or rural conditions. Quality and permanence is rightly esteemed, as also simplification of maintenance and the avoidance of periodical or annual treatment.

(A) MATERIALS RE-COMBINED AFTER INITIAL BREAKDOWN.

This grouping is intended to cover materials composed of aggregates occurring as natural particles or which have been crushed and screened to definite sizes, and re-combined with a binder or agglomerating agent to form a carpet layer or body of material.

1. *Tarmacadam.*

This process, originally devised about 1878 as a means of constructing footpaths was re-developed as a mode of road surfacing to combat mud and dust, and has for some long time been regarded as one of the most important standard surfacing materials.

Aggregates consisting of broken stone, of suitable macadam size, either blast furnace slag, granite, whinstone or hard mountain limestone, is graded, dried and re-combined with a matrix having high agglomerating properties. The real success and permanence of the result resides in the tackiness, density and dependability of this matrix, together with the obvious precautions of skill and care in adapting and mixing the constituents.

The chief matrix or binder is based on coal gas tar, but this alone, or in a crude state, contains water and light oils, which possess no "sticktion" value, and therefore dehydration, distilling, or, best of all, after-treatment and combination with other ingredients tending to enhance its tackiness and density must be adopted to produce the most reliable results.

An interesting variation of this mode of construction is the "penetration" or "grouting" method, in which clean dry macadam stone is spread and partly consolidated. The heated matrix is then poured into the voids and interstices, and finally consolidated. The process, though un-mechanical, is yet capable under skilful and standardised conditions of producing excellent road surfaces. Bitumen also is largely used as a matrix under this latter process.

In both the foregoing systems, procedure has become largely standardised, and will produce road surfaces satisfying all traffic demands for medium densities of traffic, and yielding a normal life value up to ten years. Indeed, many instances exist where roads are still in excellent service which were built 15 or more years ago. They have, of course, in the interim been carefully maintained and systematically surface treated.

2. *Concrete.*

The principal properties of Portland cement concrete have been well known for a great number of years, and it has enjoyed a well-deserved vogue for foundation work on roads. Of late there has been a tendency to emphasise its value as a method of road surfacing, and its enthusiasts claim for it that it provides a complete answer to demands for a perfect road surface.

The story of the concrete road is an old one, and dates back to the first earliest efforts made in Scotland about 1865. Many engineers during the last 30 years have been attracted by this problem. Each has experimented in turn and each has achieved a partial success and a partial failure. The problem is a most tantalising one, and is made still more difficult by omission to recognise and allow for the natural and unalterable laws of temperature expansion and contraction.

The co-efficient of expansion for concrete is .000066 per degree Fahr., and while the diurnal range of temperature is not to be ignored with its alternation of stress, the seasonal variation is serious, and may cover a range of temperature of 63° Fahr., *i.e.*, 22° Fahr. to 85° Fahr. On a 50ft. slab this means an expansion of .234 inches, say, $\frac{1}{4}$ in. If held between rigid abutments at ends, this is equivalent on a road-slab 24 feet wide and 8 inches thick to a compression stress of, roughly, 800 tons.

In road work without expansion joints, such a stress is cumulative longitudinally to the road, and unless dissipated or equated locally it does, in fact, in practice cause serious damage.

A method has been devised for equating these stresses throughout the road upon each bay joint, and some success has been achieved.

The full exposure of concrete without protection naturally induces the maximum temperature stresses and so accelerates breakdown, leading sooner or later to its eventual covering by some surfacing medium. So far as results have gone to date, the problem is still unsolved, and the perfect road has yet to be achieved.

The advantages of concrete in foundations are :—

- Rigidity and power of distributing loads over large areas of bad foundation.

- Long life when protected by surfacing from impact and temperature.

The disadvantages of concrete as a wearing surface are :—

- Its lack of resilience as a wearing surface.

- The difficulty of eliminating temperature stresses.

- Vertical movement of slab against slab on transference of load.

- General inefficiency of expansion joints.

- Seeming ease of manufacture, leading to loose methods and lack of uniformity and of precision.

Despite these pros and cons, concrete has a most definite and valuable place in road construction, especially in foundations, and is referred to here as a surface mainly because of the zealous claims made on its behalf. It is yet too early to express any opinion either for or against on the results of the more recent works.

Certainly rapid progress has been made of recent years by the use of alumina and rapid hardening cements, and much good research work is being done on this question to-day.

(B) BLOCK SYSTEMS OF PAVING.

1. *Stone Sett Paving.*

Probably the oldest forms of paved road construction consisted of blocks of stone roughly dressed to some regularity of shape, and laid more or less systematically with the upper face so set as to give a reasonable travelling surface. For this class of paving many varieties of rock have been found suitable, both from sedimentary and igneous formations.

Stone sett paving has passed through various stages, chiefly in the direction of smaller blocks with broad open joints affording a good foothold for horse traffic. In the more modern form to-day, stone is utilised from granite quarries which cleave readily in all directions, and with a large size block and greater precision of dressing, a fine joint is obtained, thus leading to a more uniform and truer surface which maintains its character under heavy traffic for a considerable period.

A further improvement has been effected by laying blocks in courses at 45° to the axis line of the street instead of the normal 90° line. By this means a further reduction in the "hammering" and "take-off" at the joint is achieved.

The essential qualities of a good granite for best modern paving work are :—

- Density.

- Closeness and regularity of grain.

- Good cleavage.

High compressive strength.

Low co-efficient of attrition.

Owing to its very long life under intense industrial traffic, it is most probable that granite block paving of the larger sizes, with close fine joints, will always remain one of the important surfacing mediums.

2. Wood Block Paving.

The earliest recorded use of wood blocks for the purpose of paving roads is believed to have been in Russia. The first blocks consisted of short uniform lengths, round in shape, as cut from the tree trunk. Later, to secure a closer joint, these became hexagon in shape, and finally received their present form of rectangular blocks as cut from the deal to a uniform width and depth, and were laid in courses. This method of paving was first introduced in England about 1838, but some time elapsed before the value of a firm foundation, such as Portland cement concrete was adequately appreciated.

Many classes of timber, both home-grown and overseas, have been tried, including English oak, beech and elm, and the pines, yellow, red and Norway. Some 15 to 20 years ago strong efforts were made to introduce and popularise the Australian hardwoods, Jarrah, Karri, Blackbutt, tallow wood, etc., but in the main these failed to satisfy the conditions owing to shrinkage, and the resulting surface wear at the joints. The most successful was Jarrah (*Eucalyptus marginata*). This has led to the predominance of the soft woods for paving, and the timbers mainly used to-day for this purpose are the *Pinus sylvestris* group, the chief source of supply being the Baltic and White Sea ports—Gefle, Harparanda, Helsingfors, Memel, etc.

Great care in the selection of timber, sorting and cutting is an essential to good work. Most important of all is the treatment by chemical means of the wood blocks after cutting. This treatment aims at the elimination of moisture and the impregnation into the pores and fibres of a suitable preservative, thus changing the state of the cellulose and lignin structure, and destroying the conditions favourable to the growth of the fungus *Lentinus lepidens*.

There are three principal methods of preservation :—

1. Zinc chloride (Zn.Cl_2) or Burnetizing.
2. Bi-chloride of mercury (Hg.Cl_2) or Kyanizing.
3. Creosoting.

The latter is the one most favoured to-day, and has the advantage, if properly carried out, of rendering the timber resistant to moisture, and more sanitary.

Wood block paving has a definite place in street work, mainly due to its power of absorbing shock and impact along the line of the fibres and grain, and is usually chosen for bridge decks and streets alongside schools, public buildings, offices and shops. Its life normally runs to ten years and frequently under favourable conditions will exceed this.

There are some minor problems connected with its use which are at times troublesome. The increase in weight and speed of heavy passenger and goods vehicles, and the large stresses set up in retardation and acceleration cause a tendency to "creep" with a consequent opening of the joints and destruction of the water-tightness and ultimate efficiency of the paving. These problems are in turn being dealt with and probably a solution has already been found.

3. *Asphalt Block Paving.*

The principle of paving by means of blocks seemed at one time to have attained such a vogue as to have been looked upon as the natural method of laying any paving material, and in development along these lines very successful results were obtained with bituminous limestone rock, pulverised and then compressed under heat and great pressure into moulded blocks, and then laid as flat bricks or tiles to form a pavement. They possessed, however, no features which could not be duplicated with advantage by sheet asphalts, which will be referred to later, and they have to-day been largely superseded by the latter. The frequency of joints always presents a difficulty, as it is inevitably at this point that all forms of block paving break down in service.

4. *Brick Paving.*

There is a class of road surface which ought properly to be referred to, initiated and highly developed in Holland over the last century, and that is the paving of street surfaces with a hard vitrified brick. It has been very extensively used also in the principal towns of the eastern States of America, where production relating to this has been highly systematized. Attempts have been made to introduce this form of paving into this country, but so far it has been subject only to very limited trials, and it is doubtful whether the conditions here are suitable for its extended adoption.

The bricks are manufactured to standard sizes from clays and shales, which contain the essential constituents to ensure complete vitrification, and the production of a dense uniform and hard brick which will not chip or fracture easily.

A typical chemical composition is the following :—

					Per cent.
Silica	Si. O ₂	...	...	...	56.0
Alumina	Al ₂ O ₃	...	...	...	22.5
Sesqui Oxide of iron	Fe ₂ O ₃	...	...	...	6.7
Lime	CaO	...	...	...	1.2
Magnesia	MgO	...	...	...	1.4
Alkalis	K ₂ O, Na ₂ O	...	...	...	3.7
Moisture	H ₂ O	...	...	...	1.5
Ignit. loss (mainly)	H ₂ O	...	...	...	7.0

100.0

Under a highly standardised system of manufacture and as a substitute for local stone supplies, good results have been obtained with moderate traffic densities, particularly where rubber tyred traffic predominates, and steel-shod and horse traffic forms only a small percentage of the total.

Owing to our resources in other directions for materials, our general proximity to quarries, etc., it would appear that there is a small outlet for this medium of surfacing roads in England.

The importance of reference to this class of pavement lies chiefly in showing that nature's resources are being carefully reviewed and exploited to provide materials suitable for modern highways.

5. *Rubber Block Paving.*

Much time, money and research have been expended upon the problem of the adaptation of so intriguing a material as rubber to the surfacing of special streets. In the limited trials which have taken place of this material over the last 25 years, some remarkable results have been obtained in the life value which it is proved to have. Its resilience, silence and absence of wear and attrition are alike remarkable, but there has been one mechanical problem upon which most of the past efforts have broken down. This has been the difficulty of anchoring the armouring or wearing coat down to the road foundation, and it has proved a much more difficult problem than was at first surmised.

Numberless patents and devices have been tried out and abandoned. It has only lately come to be realised how great are the horizontal sheer stresses set up by modern heavy traffic units. The joint between block and block has also been a source of distress. There are indications, however, that at least one good example is now available, which has overcome the question of anchorage, and after 12 months' use in full service, carrying 60,000 tons per day, shows no sign of distress or even of wear. If the promise of its first year of service is maintained, it will be difficult to forecast a total life value for this class of material.

The initial cost of construction, therefore, though heavy, may in time be completely justified to the frontagers, who, after all, are vastly interested parties, by an increased immunity from re-paving and reconstruction. Incidentally, while there is a slight diminution of road noise from the use of rubber pavement, what remains in the shape of mechanical noises from motor vehicles is still alarmingly high. One of the chief advantages which its use disclosed was a reduction in the vibration transmitted to adjoining buildings. This is a factor of increasing importance, and would alone go far to justify a most interesting development in the road surfacing treatment of dense cities.

PLASTIC OR MOULDABLE MIXTURES LAID AS A VENEER OR ARMOURING COAT.

This is an important group, and one holding out great promise of future

development and progress. The basis of this series, in all its forms, is the use of bitumen, both in its natural form or as derived from petroleum oils by distillation.

1. *Compressed Powder Asphalt.*

This, the oldest form of asphalt paving, consisted in the use of a peculiar group of limestone rocks, which have become naturally impregnated with bitumen. The lump rock is ground into powder, then heated or roasted. This powder, after being spread carefully, is compressed with hot rammers into a continuous sheet. It is much used for town and city streets under dense traffic conditions, where the relative speeds of traffic movement are slower. It has a long life and is a most reliable surfacing medium.

2. *Mastic Asphalt.*

The next important development was mastic asphalt. The creation of this type was based upon the preceding, but modified to obviate certain of its disadvantages. This was secured chiefly by the addition of larger quantities of mineral matter and aggregate, with the addition of a small percentage of bitumen. It can be brought to a plastic state, in which condition it is laid and floated by hand upon the foundation. It has undergone of late rapid development to adapt it to modern conditions, and it makes a very true type of surfacing which upon a good foundation will serve for a great number of years.

3. *Asphalt Macadam.*

These types were evolved in the reverse direction. Appreciating primarily the special virtue of bitumen as a binder and matrix, there developed the effort to create virtually a concrete by the combination of this binder with larger size aggregates on a definite and scientifically graded scale.

The possibilities of this class of pavement was first appreciated in the U.S.A.

There is an extensive range of types following this general characteristic, utilising different proportions and different sizes of aggregates based upon a steeper or flatter grading scale, but all following the same general constructional principle. They have developed along a complicated technique.

The vital characteristic in this work is strict scientific and chemical control of the work throughout all its conditions, and the correct proportioning and adjustment of the mixture to the working conditions which have to be served.

The general object is the production of a material of maximum density and life value, whilst preserving a plastic or resilient characteristic reasonably free from tendency to deformation.

The final surface texture has of late received much special attention with the object of providing the maximum frictional resistance and road-grip.

These pavements have in their various forms special attributes, and the group generally appears to be one of the most important and valuable in modern road work, and by reason of its great variety and power of adaptation holds out much promise of future progress.

TABLE OF COMPARATIVE PERCENTAGES AND GRADINGS OF STANDARD ASPHALT PAVEMENTS.

	Com-pressed Rock Asphalt.	Mastic Asphalt.	Asphalt Carpet.	Asphalt Concrete.	Two-Coat Asphalt.	
Thickness	2"	2"	2"	3"	1½" Carpet.	2½" Binder.
Bitumen	% 12	% 9.36	% 9.36	% 7.8	% 11.98	% 8.4
Passing sieve 200 mesh		24.80	13.44	10.2	19.38	1.4
100		7.04	8.48	7.0	12.70	3.2
80		.72	3.82	.8	3.46	.4
50		5.44	23.70	15.2	28.58	5.8
40		4.68	8.48	10.6	9.86	4.6
30		3.72	6.44	3.0	6.74	3.6
20	88	3.56	4.06	2.6	4.10	4.8
10		7.28	3.96	6.0	3.20	2.2
1½"		5.56	1.64	36.8		.4
1¼"		17.60	6.56			1.2
1⅜"		10.24	10.06			—
1½"						20.0
1⅜"						22.8
1"						21.2
Total ..	100%	100%	100%	100%	100%	100%

EVOLUTION.

One aspect of modern road surfacing contains, in my submission, a paradox. The principal impetus toward improvement came from the endeavour to cope with the dust and mud fiend, which all too literally followed from the new mechanical traction set free by the passing of the Motor Car Acts.

In the process of curing this evil, it was suddenly realised that the surfaces so obtained were surprisingly better and smoother for travelling, tougher and more resilient, and thus had a longer life value. This is the principal phase of surfacing work which now predominates. The actual range of betterment achieved can be realised by any carping critic recalling the conditions in other lands, or by his visiting some of our little known and unimportant by-ways which reflect with some accuracy both in their narrowness and irregular rough surface the conditions of our main roads of the early motor car period.

CORRUGATION.

A review of the road surfaces of to-day would fail of its purpose if it contained no reference to certain minor defects which exist, and which so far have not been entirely eliminated.

Of these, the most scientifically interesting is corrugation, or wave formation. Commonly, this is more pronounced and emphatic in the more plastic materials, and certain clear evidence of flow is discernible. It is impossible to dogmatize, for deformation amounting to corrugation is also observable in the rigid materials, such as concrete and wood-block paving.

An easy and convenient theory is that corrugation is caused by steam rolling. This is too obvious and ready an answer, and is only partly true, in so far as it initiates the minor deformations at the preliminary stage.

The author's view is that the real explanation lies in stresses set up by fluctuations in impact or loading due to the springing of vehicles, and that there lies a definite ratio between the periodicity of a vehicle spring, speed and wave frequency. This can be more closely realised when examining the case of wave formation where a certain type of traffic predominates, *i.e.*, a regular motor 'bus service at close intervals, and noting that the loading imposed upon the road is not constant or static in value, but is constantly variable and ranges from a negative to a high positive value.

We thus get these successive blows which originated at a minor deformation or obstruction magnified in amount, spreading rapidly along the surface to attain in some cases a very definite and well-marked period and amplitude.

THE CO-EFFICIENTS OF FRICTION.

A road surface of whatever type of construction has a co-efficient of friction with a value constant to that surface, but which varies in amount between surface and surface, and has a separate value for varying atmospheric conditions, *i.e.*, dusty, clean, moist, wet, or more simply, whether dry or lubricated.

The value of such co-efficient has a meaning in securing the necessary adhesion between the wheel and the road, to develop the full propulsion effort of the prime mover, and so prevent wheel-spin, especially when accelerating, and, lastly, to secure safe and rapid retardation.

There is at times much loose criticism of road surfaces in relation to this question, and since a scape-goat is necessary, the road no doubt serves as well as another, since it is impersonal. This criticism is all directed to the fact that skidding, or more truly, sliding, takes place under certain well-known and obvious conditions. Surely in so important a matter as this, the sole question is one of fact. So far absolute records do not seem to be available, and the author has, therefore, prepared the following table, which he puts forward as an indication of the approximate values which may be assigned to principal groups or types of surface:—

CO-EFFICIENTS OF FRICTION μ OF MAIN GROUPS OF ROAD SURFACING MATERIALS.

Material of Surface.						Dry.
						μ
1.	Rubber on Rubber	...	...	...	...	.693
2.	Do. Tar treated surface (including sprayed, grouted and tarmacadam)	...	...	...	...	.494
3.	Do. Bitumen (including all types of asphalt or bitumen treated surfaces)	...	...	...	...	.597
4.	Do. Wood Block Paving	...	...	...	...	.590
5.	Do. Concrete	...	...	...	...	.486

THE ROAD VEHICLE.

Any review of this subject, however sketchy, would fail of its purpose and usefulness if it left out of consideration some account of the relationship between the surface and the traffic which uses, and indeed calls it into being.

The problem is really a dual one, in which the interests of both depend upon the qualities and behaviour of the other partner, and indeed these are virtually inseparable and reciprocal. Recognition of this quality of dual interest is slow and tardy, but it does undoubtedly grow and develop, no doubt largely fostered by the quickening impulse of self-interest.

The author in 1920 had occasion to instance the needless maintenance burdens which were occasioned both to roads, foundations and to the vehicles by reason of the persistent misuse of the solid rubber tyre equipment for motor vehicles often travelling at high speeds. The shattering effect of the impact both to the road and the vehicle was a serious and costly superfluity. The remedy advocated was the greater use of the pneumatic tyre for the larger road units for cushioning loads and minimising impact and blow to both. Of late years great strides have been made in this direction.

This illustrative point has been referred to in detail as a phase of evolution in the real "road user" sense, which should be fostered and encouraged by research and inventiveness.

Further progress in the direction of what may be called the "roadworthiness" of vehicles has been made in the improvement of brake equipment, particularly in the adoption of four-wheel brakes, and again in the lowering of the centre of gravity in certain types.

At this point, however, it is submitted that from our particular standpoint the record of evolution comes to an abrupt end, and the vast numbers of new units which annually swell the flood of traffic on our highways almost rigidly conform to type. Perfected and refined in detail or comfort, it is true, but in effect "Standard" so far as acceptance of principles of design and lay-out is concerned.

Take another point as a field of research—Springing. Vehicle springs which attain their maximum efficiency with a fully loaded vehicle are for the

empty vehicle hopelessly inefficient, particularly when the ratio of loaded spring weight to unloaded spring weight is a high one. Consider the rear springs of a motor lorry designed to carry a loaded "rear axle load" of 4.3 tons nett, but which when empty have only to sustain the unloaded tare weight of 1.2 tons; the springs now have virtually ceased to function as such.

No existing system of leaf springs can cope with such a range, and it is submitted that some form of compensation of spring to load should be the subject of research.

In relation to road surfaces, the contact of the vehicle is secured by its tyres, and it is precisely at this point that the modern pneumatic tyre, excellent as it undoubtedly is under modern scientific control and improved manufacturing processes, falls short of perfection. The tyre which, when new and with the pattern of tread chosen by the maker will give excellent adhesion and security under dry weather conditions on most types of road surfaces, shows a marked falling off when the road is partly or wholly wetted. Now under the vagaries of our climate we must anticipate that the roads must be wetted for the whole or a part of 200 days out of the 365 in an average year.

The question may fairly be asked—does the modern tyre equipment make all the provision that it should for this known condition which persists throughout its running life, and for the equally serious condition when the tyre tread has wholly or mainly worked off, and the original and only provision of the maker to secure the necessary frictional adhesion both for acceleration and retardation has nearly disappeared. At this point again it is submitted that further evolution is called for in view of the speeds and momentum in common daily use, and the density of traffic flow, and that modification should be sought either by partial combinations of rubber and other materials or by a radical change in the principles of design of tread.

The introduction of the balloon or low pressure tyre has not been lost sight of, but the enormous increase in the number of new vehicles per annum, the increase in speed, in new drivers and, therefore, lack of skill, and, to sum up, the all-round increase in danger, justifies a most searching review of the position and a frank attempt to aid in solving one of the most difficult road problems with which we are faced.

Figures have a clear message, and the true values of the co-efficients of friction should be established under all weather conditions, and then be utilised to influence tyre design.

ROAD SAFETY.

Bound up very closely with the subjects of road surfaces and their users is the question of road safety. The first exist for the service of the second through the medium of the latter. The roadworthiness of the vehicle and of the road have their common denominator in road safety. Each must contribute its quota to the common cause or even a little more, because there

is yet to be allowed for as a factor of safety, often a factor of ignorance, the unknown personal equation of the driver.

FACTORS CONTRIBUTED BY ROAD.

1. Clear alignment.
2. Easy gradient.
3. Flat camber.
4. Super-elevation for curves.
5. Open road junctions.
6. Clear warning signals.
7. Road surface of uniform and granular texture true to profile and free from distortion.

FACTORS CONTRIBUTED BY THE VEHICLE.

1. Efficient transmission of power.
2. Brake equipment.
3. Springing, compensated to load.
4. Tyres which will give adhesion in all weathers
5. Low centre of gravity.

FACTORS CONTRIBUTED BY THE DRIVER.

1. Personal skill.
2. Driving sense.
3. Control of speed.
4. Judgment.
5. Response.
6. Courtesy.

An ever present example of the operation of these three factors in combination is that state of road conditions which tends to bring about a type of accident called a skid.

Under these conditions, while the analysis is far from complete it is certain that some of the factors mentioned above under the three main heads—the Road, the Vehicle, the Driver—have possibly in combination brought about the state of instability called a skid. It is also fairly certain that no single cause is solely responsible and it is finally equally certain that by improvement and development along the lines detailed under those important three heads, and not by any one alone, road traffic conditions will gradually tend to become more perfect.

FUTURE EVOLUTION.

That roads must and will play a more vital and intimate part in our economic life there is no gainsaying. They formed the earliest and simplest means of

human movement and communication and have with us persisted as an integral and necessary part of our social structure as evidenced by the creation of public highways throughout England to the extent of one mile of road per two-fifths square mile of English soil.

All road work is a steady growth, built patiently upon the labours of the past, the many failures and the few successes. All is trial and error, but essentially trial, so that perfection can never be achieved, because to the engineer and scientist there is no final perfection which shall not in its turn be regarded as a field for new endeavour, new hope, and a greater worthiness. So only may he aspire to make "the crooked straight, and the rough places plain."

DISCUSSION.

THE CHAIRMAN, in opening the discussion, said the lecture had been full of material, and the lecturer, by descending into the minutiae of technics with such an audience before him, deserved the Victoria Cross; but with all that audacity he had shown an amazing discretion, because he (the speaker) had been listening very intently to see whether he would give a poor, ignorant person like himself some guide as to whether there was anything in favour of the bitumastic road covering or the asphaltic road covering. He had wanted light and leading, bearing in mind that as an ordinary member of society he used road surfaces, as to what was in fact, in the opinion of the lecturer, the most efficient road-finishing surface for all kinds of traffic, including the traffic of that much-neglected person, the walker. He was also thinking of the sportsman who recently protested bitterly to the bench of magistrates, when they summoned him for riding on the footpath, that these great engineers and road specialists were providing roads which enabled him to kill his hunters. He had wanted light and leading, but with that amazing discretion of the old official which Major Clements had shown throughout his discourse, he had avoided committing himself, and had left his Chairman in rather an unfortunate position.

As a quite uninformed person he wished to make a few remarks on the problem of roads as it presented itself to him as an ordinary person. He would give all those gentlemen who were concerned with the provision of roads one tip: not to forget the pedestrian, because they would be pedestrians themselves some day; and further, when they provided those magnificent racing tracks for those who could afford the new Ford car, he suggested to them that they might make a little provision for that courtesy which the lecturer had put last, and which might have come a little earlier! The pedestrian would probably be squared if engineers provided together with their great racing tracks a means of getting over the country without having to face the dire penalties of trespass. The other thing that occurred to him as an ordinary user of roads was this: He could not believe that a road surface would be efficient if it involved a material which had to be separately jointed at intervals of every few inches of length and width. Bearing in mind the enormous length of roads, and bearing in mind the horizontal stresses set up, to which Major Clements had referred, he could not believe that with the fast and heavy traffic of to-day an efficient road would be got if it involved the use of a surfacing material with a maximum number of beddings and cross-jointings. Another aspect of the problem which had to be borne in mind was that the provisional period of peace

which we were at present enjoying was not likely to last, from all accounts, and it had to be borne in mind that road engineers had a great duty to perform in the future in view of the enormous danger and incidence of hostile aerial attack. The one thing which, from reading the papers and from watching the tendency of opinion, occurred to him was that in the future it would be very much more "Cuthberty," to go out into the trenches than to stay at home in London under hostile aerial attack. He was certain that the "Cuthberts" would in future all be found in the trenches; and therefore, bearing in mind that all the brave fellows would be at home, and that amongst those brave fellows would be the wives and the mothers and the daughters and the sisters—often the bravest fellows of all in emergency—and bearing in mind that they had got to sit tight in the most dangerous position, he thought road engineers ought to remember that they must produce a road surface which would be readily de-contaminated if the enemy poured a mass of mustard gas all over it. He had noticed in the Press a few days previously that Lord Lee of Fareham had written a letter of protest to the *Times* against the proposal to use wood block paving in one of the great London roads; but his lordship, with a great knowledge of the subject, did not in his opinion bring out the fundamental importance of the point that, in the event of a future war, and in the event of the enemy being able to deliver a successful aerial attack upon London, it would be more dangerous to walk about London after the attack than to be in it during the attack, because if there were those permeable roads with wood block pavings which allowed the interstices to be filled with mustard gas and other deleterious materials, we should all have to stay in our houses until it had been cleared away, and that would take some months. It therefore had to be borne in mind that the problem of road construction was not only a peace problem, and had got to include much wider considerations in the future than it had in the past.

If road engineers went on making their roads as they had been doing in the recent past, they would drive many people to grow wings. He was sure they would all do that naturally when they went to other spheres, but before they got to that happy time the wings were needed. When he used one of the new roads it filled his soul with longing to bomb the engineer who made the road. In the first place, the engineer took what was always called the shortest way, and if there happened to be a beautiful bit in his path, he said that must not stand in the way of it. Naturally the engineer represented Progress, and the cottage did not. If he had to cross alluvial land, he built great embankments with great ridged scars of mounded earth to carry his traffic. It made him think of the country torn and bleeding under the horrid attack of the road engineers! He suggested that they would never succeed with the art and science of road making unless they took æsthetic considerations into account, unless they considered not only the necessary efficiency of the road but also took necessary consideration for matters of beauty, and for protecting and preserving those rural amenities which were so distinctively the possession of England. After all, it was a very practical consideration, he suggested, because in the future, as one gathered from our American cousins, we should all be caretakers of our own cottages and halls in the future; we should all be doing no business, because we were "down and out." Therefore, why not protect those cottages and halls, when we should all, our heirs, executors, administrators and assigns, be caretakers? Why should not the road engineers, when they were driving their great highways, consider æsthetic values as well as those important material considerations with which the lecturer had so efficiently dealt that evening?

In conclusion, the Chairman invited those present to deal with any questions which arose out of Major Clements' lecture, and to give the meeting the advantage of their points of view.

SIR WILLIAM GEARY asked permission to raise a point which did not altogether arise out of the lecture, but out of the statutory duty imposed upon those who had control of the roads. He spoke as a member of the Kent County Council, and wished to refer to the admirable remarks of the Chairman about "bleeding under the strokes of the engineer." There was a very substantial gash at Wrotham Hill.

He hoped he might be allowed to touch upon the subject of roadside trees. Within the last three years Parliament had conferred upon county councils, rural district councils and parish councils the power of planting roadside trees, but the Kent County Council, notwithstanding that power, had refused to grant any moneys for trees whatever, and on this point he desired the opinion of the lecturer. There had been a report from the Kent Road Surveyor, for whom he had every respect, that the disadvantages of planting roadside trees cancelled the advantages, because of the damage to the road surface, and no doubt this had been so in the past. There was, in fact, a law that no tree should be planted within fifteen feet of the centre of a road. But now, although Parliament had given those powers, yet the Road Surveyor for Kent had said that the damage resulting from planting trees at the roadside was greater than the benefit. As regards the benefit and the amenity, he could leave that subject to the eloquent remarks of the Chairman; and in regard to the damage, as against the opinion of the Road Surveyor he had the authority of Parliament and also the practice of the United States of America, where roadside trees were planted at the public expense, and also the practice of France and the more progressive Continental countries. When he was in Paris recently he had happened to put the question before one of the authorities for the suburbs of Paris, who replied that the possibility of damage to road surface was negligible, but said that the expense of trimming the trees came to about 15s. per tree per year, which was a serious expense. As regards the question of damage to road surface, he would ask the lecturer to enlighten the meeting, and if he would do so, then he in turn would try to enlighten the Kent County Council.

MR. W. J. U. WOOLCOCK, C.B.E. (General Manager, Association of British Chemical Manufacturers) said he was sure that everyone present had thoroughly enjoyed the lecture. He would go further, and say that for the perfect enjoyment of any lecture delivered from that rostrum one must have had the responsibility of delivering a lecture from it. The Chairman had commented on the discretion shown by the lecturer. Discretion, however, was rather a negative virtue; and he thought he might quite safely go on to add to that the positive virtue which he had discovered in the lecture, namely, its balance. That balance had perhaps appealed to him more than anything else. He knew a little, about one per cent., of what the lecturer had been talking about, yet he was able to follow completely one hundred per cent. of the lecture because of the delightful balance which the lecturer had been able to put into it.

He was also grateful to the lecturer for having laid down definitely what constituted a perfect road surface. He believed that the seven points which were laid down were points which those who were responsible for the making of road surfaces would endeavour to work to. Later, when the lecturer was speaking about tar macadam, there was one point which had arisen in his (the speaker's) mind on which he would like to have the lecturer's opinion. The lecturer had said that the real success and permanence of the result resided in the tackiness, density and dependability of the matrix, and he wondered whether one ought not to add to these the factor of gradation. Perhaps it could be inferred from the reference to density.

He also wished to put a question with regard to "penetration" and "grouting." It would be very useful if the lecturer could give an indication as to whether, in his

opinion, grouting was likely to increase, or whether it had reached its maximum point, and might be expected rather to diminish in use. A lot would depend, from the point of view of industry, on the answer to that question, and it was something which industry would like to try to anticipate.

It had been suggested that if one wanted to look for improvement in the treatment of road surfaces, improvement could only lie along the line of putting the road dressing on the road while it was hot. That had been represented to him as a panacea for many of the difficulties that arose. He was told that if he would only see that the road dressing was put on hot, then half the difficulties from which he suffered at the moment would be overcome. It did undoubtedly give increased traffic capacity, but whether, from the point of view of permanence the hot mixed process was one to be recommended he did not know; and there, again, he was anxious to have further information.

He had one other elementary point to raise. The Chairman had referred to wood blocks, and the necessity of taking up so many hundred blocks for a small area in the road when it had to be repaired, or for other reasons. What he wanted to ask was whether any attempt had ever been made to lay a road in trays, say, six feet long and six feet broad. Was it possible, for instance, to lay a series of trays on iron girders along Piccadilly—trays which could quite easily be taken up so as to enable one to get at the pipes, and so on, without breaking up the road; and if not, what were the mechanical objections to attempting a road on trays?

MR. NORMAN SCORGIE (Past President, Institution of Municipal and County Engineers,) said that for those who had spent their lives in roadmaking it was easy to appreciate the point made by the last speaker about the excellent balance of the paper. The lecturer had expressed no opinion on the merits or demerits of any particular phase of construction. He had expressed no preference for one form of construction, whether tarmacadam, asphalt, bitumastic or wood paving, and therein he had been very wise, for in looking round the room and seeing those who had come to listen to the lecture he perceived that all the vested interests were well represented!

He could hardly think that the Chairman in his remarks had intended to cast a slur on engineers, in suggesting that they cut ruthlessly through beautiful old cottages. Everyone knew the interest which the Chairman took in the preservation of our old cottage architecture and ancient monuments, but he felt sure that there was no engineer who was worth his salt who would not prefer to go round rather than ruthlessly uproot a cottage. The Chairman had also said something about taking a road through a cutting. It had to be borne in mind, in this connection, that there were certain limitations in the Ministry of Transport regulations as to the gradients of roads, and in going round one might get into some populous village instead of going through virgin country.

He wished to associate himself with the remarks of the gentleman who had spoken about trees along highways. He knew very well the Engineer of Kent, and he could not for the life of him understand his objection to planting trees along highways. If he had only travelled through France, Switzerland and Austria he would have seen the thousands of trees that were planted on both sides of the roadway in those countries without any detriment to the road surface, and with the very great advantage that when one was travelling along the road one did not see a long blank line in front, but pleasant foliage on both sides. It was also an interesting point that the countries where those trees were planted must derive an income from them, because most of the trees were apple and pear trees.

In conclusion, he expressed his best thanks to the lecturer for the very interesting lecture he had given, which would be beneficial to all those who had the road problem at heart.

MR. OLIVER E. WINTER (late Municipal Engineer, Borough of Hampstead) said that, like his friend Mr. Scorgie, although he had put off official shackles, he had still a considerable interest in what had been his life's work. For over thirty years he had been in charge of roads in London areas, and he heartily supported the encomiums that had been passed upon the address to which they had had the privilege of listening. He was particularly pleased that the lecturer had referred to the question of vehicles as well as roads, because, after all, they were part and parcel of what was really the same machine. Like the locomotive and the rail, their interaction one on the other should be considered, and he thought that the manufacturers of vehicles had not given that amount of attention to the subject that even the road constructors had given. Tyres and springs should receive more consideration than had been given to them.

There was a further point which had not been mentioned, namely, with regard to very heavy vehicles carrying several tons. It seemed to him an advantage that they should have six wheels. They were being introduced to some extent, and he thought it would be a great relief to road engineers, and would simplify their problem, if the weights of those very heavy loads were distributed over three axles and the six wheels. Major Clements had given an admirable summary of the present position of road paving. He agreed with the lecturer that bitumen promised to be a very useful material in connection with roadmaking, but he did think it was important that the value of British tar should not be overlooked. Properly standardised, it was still a most useful ingredient, and it should be used to its fullest extent. At Hampstead he had laid the Spaniards' Road along the top of the Heath with tar macadam twenty years previously, and it had practically had no repairs, or very few repairs, beyond an annual dressing of tar and chips, and for a comparatively narrow road it bore a fairly heavy traffic. When tar macadam was laid with a proper tar as binder, it was a very useful road. In many parts of the country proper attention was not given to the proper standardisation of the tar. He thought that possibly the Minister of Transport might give a lead towards a better standard specification for tar throughout the country than existed at present.

With regard to bitumen, the lecturer had not referred to one material which was likely to come into greater use, namely, cold bitumen. He had seen several useful examples of it in various parts of the country, and it seemed to him that where a cold bitumen could be used without the necessity of having a lot of apparatus for heating, which involved considerable expense, it was an advantage, especially in country districts, and, further, it could be used at most times of the year, in all weathers, which was not the case with hot bitumen, as it was essential for the successful use of hot bitumen, especially in the grouting process, that the weather should be dry, otherwise one would not get a satisfactory road.

With regard to the lecturer's remarks on block paving, all the main roads at Hampstead were wood paved. The lecturer had mentioned a road which had been down for seventeen years. He himself could instance several roads which had been down for more than twenty years. The road outside the Hampstead Town Hall, for instance, had been down for over twenty-six years, and was still in excellent order, and would probably go on for another ten years if it received the treatment he had given it for the past twenty years—a dressing of hot tar and sand in dry summer weather to make it watertight.

MR. W. P. ROBINSON (County Engineer, Surrey) said that the lecturer had not mentioned one feature which he regarded as important namely, the education of the engineer himself. He thought this country was suffering to-day from the lack of education of the highway engineer in the past. Speaking as a highway engineer, he was sure he was expressing the opinions of his colleagues when he said that engineers were very much indebted to Sir Henry Maybury for the work he had done towards establishing a Chair of Highway Engineering. He thought that that step would ultimately lead to much better results in road engineering than had hitherto been seen.

There were one or two simple things in the paper which had struck him—and the simple things were often those that were overlooked. He had had an illustration of that recently when he saw a patent wheelbarrow with a caterpillar track. He wondered someone had not thought of that before; it was one of the most useful things the road engineer could have. The lecturer had mentioned the question of 45° joints in paving. It often occurred to him why that principle was not applied to nearly every form of road surfacing. It was used very seldom with setts, wood paving, and asphalt. He personally always used it in asphalt. The advantage was so obvious that he could not understand why it was not applied more frequently.

With regard to concrete, he had done a little concrete surfacing work, and had suffered for his pains. The lecturer had said that even concrete was liable to corrugation. He would be much obliged if the lecturer could inform him where that could be seen. He was referring to a concrete surfaced road, not a concrete road with blocks on it, where possibly the blocks might transfer their inequality to the concrete underneath.

He was very glad that the lecturer had set out the co-efficients of friction on various types of road surface. He remembered about two years previously reading a publication by a Research Board in the United States, in which practically the same figures were set out, and it all led, he thought, to the one conclusion, that the skidding of motor vehicles was not due to the surface at all, whatever the type might be, whether bitumen, tar or concrete, but was due to the atmospheric conditions and the state of cleanliness or uncleanness in which the carriage-way might be at the time. It did seem to him on that point that if the Press could give a little more publicity to this matter of the friction co-efficients, and the scientific principles involved, it would do a great deal to help the engineer to meet the criticisms he got for making what were said to be skidding surfaces. It might also be pointed out that the motorist paid a very small proportion of the cost of keeping carriage-ways clean, which was largely done for his benefit, to prevent the surface becoming in a state liable to produce skidding. The co-efficient of friction of concrete showed up badly against the other surfaces in the table, but there were different degrees of finish in concrete. Concrete might be made with a rough surface, so that the co-efficient of friction could be very greatly increased, probably to a much higher degree than that of the other materials given in the table. He held no special brief for concrete. He had tried it, because finance had induced him to do so. In Surrey they had cheap gravel, cheap sand, with no stone, and they used local materials to make concrete, and they were thus able to produce a new road at probably a good deal less cost than by using materials other than concrete.

DR. PERCY SPIELMANN said he had listened with very great interest to the admirable survey which Major Clements had given, and he felt that "The Evolution of Modern Road Surfaces," could be carried one stage further by pointing out a way in which that evolution could be carried on. Up to the present time it seemed to

him that the evolution of roads had been an engineer's job, and now he ventured to suggest that the time had come when the chemist and the physicist must take their part. The increasingly heavy traffic that had developed called for every ounce of strength from the road surface, and yet at the present moment practically nothing was known about the fundamental factors which went to give that strength. Taking, for example, the tar and bitumen roads, where the binding material was in contact with mineral matter, the stability of the road depended on the viscosity of that material, and on the adhesion of the mineral matter and the bitumen or tar used. That adhesion and viscosity were matters for the physicist or chemist to study. The composition of tar and of bitumen was a colloidal chemical matter, and yet roads were continuing to be made in almost complete ignorance of the fundamental properties of those materials. These matters were being studied in France and Holland and America, but he believed that nothing was being done in this country except, perhaps, in a sporadic way. That research could, he thought, be very well carried on if there were funds allocated for it. He believed that the Ministry of Transport was willing but the Treasury was weak, and if even one per cent. of the Road Fund could be allocated for research for one year, an enormous amount of work could be done in obtaining an understanding of the properties of important road-making materials.

MAJOR CLEMENTS (in reply) said he had been asked to define more clearly what was the perfect road, and his lecture had been criticised because it did not define which of all the materials specified was the perfect one. The answer was that there was no perfect one. There was no perfect medicine that would cure every disease ; it did not exist ; and the road problems were road diseases, each of which had its own particular cure, more or less permanent ; and what, if anything, he had tried to stress very generally in the paper was that each of these materials had its particular applicability. He had tried to outline those road materials which had been evolved under the limited knowledge of to-day ; certain materials had been brought into use and had persisted, while others had been tried and abandoned ; they had not quite stood the test ; but those materials which he had mentioned rather briefly in his lecture had stood up to modern conditions, and could more or less be depended upon for their appropriate uses. There was no perfect road material that would cover every known condition of things throughout the country. That, he thought, was the only answer he could give on that point.

The Chairman had quite rightly asked a question which, frankly, he had not had in mind, namely, the position of the pedestrian. He also had had the good fortune to be present in that hall when quite recently an excellent and witty lecture was given by Col. O'Gorman, with all the charm and grace that an Irishman could impart into such a subject, on the question of the pedestrian, and that had been quite sufficient in itself to keep him, if he had had any leanings in that direction at all, away from the subject of the pedestrian on roads.

The Chairman had also referred to another point which he had, fortunately, mentioned in his lecture, and that was the question of courtesy in the use of the road. He had made a mistake, he quite agreed, in putting it last instead of first. If there were greater courtesy between road users upon the surfaces that some of those present provided for their enjoyment, he thought that almost nine-tenths of the accidents would be eliminated. It was just that quality which was most needed.

Sir William Geary had raised the question of roadside trees. He was glad the point had been raised, because it undoubtedly had a bearing upon road surfaces. From the point of view which was stressed by the Chairman, the æsthetics of road

work, it was a very proper thing to bring forward, and his answer on the question of trees or no trees would be this : that he would put up his hand every time for trees, with the qualification that he would not go in for the planting of trees at mechanically regular intervals along English highways. There was sufficient diversity of scenery and types between one mile of one road in the same county and the next mile, or between one county and the next county, to justify one in thinking that a standardised system of planting out a certain class of tree at a mechanical interval of x feet was not the best solution of the problem. The most effectual results that he had seen in roadside verging had been achieved on roads where a group of trees, two or three or five, at irregular intervals, acted as a point upon which the eye could rest in one's busy passage along the road, and had really, by its simplicity and by its rarity, lingered longer in the mind. He had certain spots on the English countryside in his mind where a piece of roadside waste had, by some inspired genius in the past, been treated in the way he spoke of ; a small group of trees had been planted there, they had been tended and cultivated, and then Nature had been allowed to do the rest. That was a rare feature, he would imagine, in road engineering, but he thought that any road engineer, who had, after all, a conscience and some æsthetic appreciation, would prefer to build in that way for posterity rather than put down trees which might or might not please. He did not think, in the main, that trees could be regarded as having any serious effect upon the surface of the road ; certainly not if used in the way he suggested.

He wished to thank Mr. Woolcock for his kindly reference to the lecture. At first he had listened to Mr. Woolcock's remarks with pleasure ; later on he had become distinctly uncomfortable. That was with regard to the quality of "balance" which Mr. Woolcock had discovered in it. He had had in his mind a picture of a gentleman who had got himself balanced on the top of a fence, and was afraid to come down either upon one side or the other ; so that he wished to assure the meeting that he was not consciously sitting on the fence, and that he was merely trying to introduce an element of proportion into his brief review.

If he understood Mr. Woolcock aright, he had some doubt in his mind as to the use of the words "tackiness" and "density" in the case of a matrix of tarmacadam. In that case the matrix was the hot binder which bound together the grit particles. There would be no grading in the matrix. It would conform to certain standards and have certain attributes, but the hot binder simply agglomerated and stuck together the solid part.

On the question of main roads in trays, it was rather interesting that the point should have been raised. He happened to know of a scheme which had been thought of along those lines. He knew of no instance of an actual experiment in which sections of road were prepared beforehand and dropped into position. Nothing he had ever come across yet quite answered that condition. As to whether or not in fact it would work out in practice, whether that would be a convenient way of getting at sub-surface pipes—which he thought was the most useful point of such a system—he was very much in doubt as to whether it would really answer that test. A certain gentleman sitting in that room had once given him some figures the significance of which was not generally realised. It was not realised what there was below a London street in the way of sub-surface pipes. If one were asked, one would say, half-a-dozen pipes, or something like that ; but he had it on that expert's authority that in a certain street not in the centre of London, the cumulative diameters of the pipes in the road equalled 5 times x , where x equalled the width of the road-way. He thought that was one of the most startling things he could put before the meeting ; and that figure was beyond question. If it was

realised that the diameters of those pipes added together equalled five times the width of the street, then it was no longer a street, it was also a channel for pipe-lines.

Mr. Norman Scorgie had put in a strong plea, and a proper one, too, against the suggestion that the engineer was a vandal. He thought that was well said, and he thought it ought to be said. The engineer had exceedingly difficult problems to face, particularly in the renaissance that was proceeding to-day. The highways were being called upon to do things in the way of sustaining traffic, acting as a channel for the tremendous ebb and flow, and it was inevitable that certain difficulties should arise, and they had to be solved in ways which were governed very largely by financial considerations, but governed also by the desire to produce the least possible disturbance in existing amenities. He did not think the engineer should really have the charge levelled at him that he was unæsthetic, or that he was a vandal, because he did know in many cases that that consideration was more often before the engineer than he got credit for.

Mr. Winter had referred to the question, not mentioned in the paper, of multiple-wheeled vehicles. He had been doubtful whether to refer to it or not; but it certainly should be there. It should be referred to as one of the changes in evolution which enabled the vehicle to get a better hold upon the road. After all, that was the function of a vehicle. It should contribute something itself in its conduct on the road. It should be enabled by its designer to travel along at certain appropriate speeds, and in a certain manner that would enable it to grip the road. A driver would tell one that he was much more safe and secure with a six-wheeler than with a four-wheeler.

Mr. Winter had also raised the question of cold bitumen. He had not referred to it in his lecture, and was glad the point had been raised. That was a material which had a tremendous vogue. It had come into use within the last few years, and undoubtedly it filled a very valuable place in road work in our climate. We could not count upon even a normal number of summer days in which the ordinary hot processes could be made use of, and therefore the cold method must be used; *i.e.*, a material must be used which could be laid cold.

Mr. Robinson had referred to something which was probably the most important thing of all, and that was the education of the engineer. There was little doubt that there were new problems springing up all along the line, each of which had got to be attacked in a different way, and for most of which entirely different solutions had to be found. It was a fact to-day that the methods of the road engineer were based on the methods of the railway engineer. In view of the questions of alignment, ease of curvature, simplification of gradients, and so on, the track itself was becoming more and more analogous to a railway track, and speeds were being made use of upon roads which were the speeds of a railway track. To that extent a newer view had come into being; there were new problems which called for a very broad-minded view on the part of the engineer, and there was no doubt an immense field in the future in the education of highway engineers. It had been very well tackled in the United States and certain of the Continental countries, where road procedure and road practice had gone upon vastly different lines to our own.

The co-efficient of friction had also been referred to by Mr. Robinson. He (the lecturer) ought to have explained that the values given in the paper were, if anything, on the low side throughout. There was a great difference between the co-efficient of friction at rest and the co-efficient of friction when moving, and in all cases, for safety's sake, the co-efficient of friction under motion was taken. It produced low values, but in the case of concrete the value did appear to be low; but it was con-

crete that had been put down by himself some 15 or 16 years ago. He had taken a value not for new concrete but for old concrete that had been subject to traffic, and in each case the values were obtained from actual roads *in situ* and subject to traffic. Mr. Robinson had also asked a question with regard to corrugation of concrete. He did know of cases where corrugation had taken place in concrete, in fact, in concrete which he himself had laid down!

Dr. Spielmann had referred to the change in the character of road work, and had pointed out that it was largely turning into a direction in which the chemist and the physicist should be of great assistance. He had tried in a rough way to indicate that that was in fact the general drift of all road work and all road surfacing work, that it was calling for methods and tests and standards which were no longer the rough-and-ready standards of the past, but scientific standards, the standards upon which strict formulæ were available and could be worked to, and as that became more the usual practice, so would the work become more perfect and more regular in type. There was an enormous amount of work being done by other nations, and he did not think that we in England were doing sufficient research work, commensurate with the enormous sum that was being spent each year on road work. With our usual British habit of muddling our way through, insufficient work was being done in that direction. He had tried to point out that the same thing applied to the vehicle—that more research work should be done on the vehicle side to attempt to overcome, if nothing else, the hop, skip and jump condition that now existed on the highways. The vehicle, to secure its maximum propulsive effort, should be in contact with the surface throughout its journey always and with an even pressure. That was a counsel of perfection, but the point was how near could one get to it, not how far away from it could one get—a condition in which the vehicle was maintaining a good and even and regular contact with the road, so that the economic value of the prime mover was utilised to the fullest extent. That was one field in which a tremendous amount of very effective research work could be done.

THE CHAIRMAN, in proposing a vote of thanks to the lecturer, said the paper had not only been brilliant in itself, but had been the cause of brilliance in others, which was the very best form of brilliance. The way in which the lecturer had dealt with the various queries which had arisen was remarkably distinctive. The moderation of statement, the clarity of exposition, had been almost a model, if he might say so, of how these difficult subjects should be tackled in discussion. He felt that he would like to have on his side a lecturer with the qualifications and the capacity of Major Clements when he was defending a forlorn cause. The discussion had been extremely interesting, and some of the points which the lecturer had made in the discussion seemed to him very valuable. He regarded as perfectly ideal his view of tree-planting on roads. As an architect, as a man who was supposed to have æsthetic considerations in his mind, Major Clements had taught him a point which he would never forget, namely, that a purely formal method of decorating roads was not the ideal way—a striking illustration of the capacity of the lecturer for dealing with matters which were usually supposed to be outside the purview of the engineer. Major Clements was a knight errant among road engineers, and if the views he had expressed were the views of the road engineer in future, he was sure the science of road engineering would break new ground, and would never be at variance with the æsthetic considerations which he had ventured to mention in his opening remarks.

The vote of thanks having been carried unanimously, the meeting terminated.

OBITUARY.

LEON GASTER.—We regret to announce the death on January 7th at his Sydenham home, after a short illness, of Mr. Leon Gaster. Born at Bucharest in 1872, he was the son of a Dutch Diplomatist, the Chevalier A. E. Gaster, and was educated at Bucharest, where he took the degree of Bachelor of Science and Arts in 1890, and afterwards at the Polytechnic at Zürich, where he worked in the Electro-technical laboratory of Professor Weber until 1895. In that year he came to England, becoming a naturalised British subject in 1902, and commenced in the following year his practice as a consulting engineer on illumination, which he carried on up to the time of his death.

From this date onwards, although he had many other activities in kindred fields, he devoted himself mainly to questions of illumination. In 1908 he started *The Illuminating Engineer*, and in the following year, with the co-operation of a small band of enthusiasts, founded the Illuminating Engineering Society, of which he became honorary Secretary. He made it his object to keep in close touch with all developments in the science and art of illumination in Europe and the United States, and for that purpose travelled abroad almost every year. He attended many international congresses and served on a large number of Home Office and other Committees dealing with questions of illumination, and was a member of the "Safety First" Council. Mr. Gaster was also well known in the journalistic world, and was a Fellow of the Institute of Journalists and honorary General Secretary of the British International Association of Journalists, a body which aims at establishing cordial relations between members of the Press of different countries.

Mr. Gaster, who had been a member of the Royal Society of Arts for over 30 years, read several papers at the Society's meetings: in 1906 a paper on "Progress in Electric Lighting," for which he was awarded a silver medal; in 1909 a series of Cantor Lectures on "Modern Methods of Illumination"; in 1913 a paper on "The Economic and Hygienic Value of Good Illumination"; and in 1920 a paper on "Industrial Lighting and its relation to Efficiency." He also made frequent contributions to the discussions at the Society's meetings when papers on engineering and allied subjects were read.

CORRESPONDENCE.

"RIGHT MAKING."

The difficulties which troubled the reviewer of B. J. Fletcher's "Right Making" (in the Journal of December 16th) seem far fetched. Why should he have dragged in theology because Mr. Fletcher's premise is that the beauty of a wave or a branch comes of necessity? Why should he think that it would be relevant or "better" to say that a table should be steady on its legs? Many tables of the worst design are as immovable as rocks and as uncomfortable to sit at. Then as regards the two chests of drawers; he happens to think the French specimen "very fine" and the other dull. But a more fastidious taste may think the first very absurd and the plain modern specimen very interesting. Preference for the ornate is not the hallmark of discrimination. But Mr. Fletcher's point was not to dispute about taste or illusion, but simply to indicate that loops of dragons and their tails do not make serviceable, and therefore good, handles. As for the Landseer and Egyptian Lions,

Mr. Fletcher's diagnosis of the superiority of the latter is in his context convincing. He says, in effect, each material has its most appropriate treatment, consonant with its special character. The Egyptian sculptor used bronze more sympathetically and imaginatively than Landseer and incidentally and reciprocally managed to endow his metal with a sort of leonine spirit. Landseer's failure to sympathise sufficiently with bronze, plus his different ideal, impaired his Lion.

Of course there can be no magic incantation to ensure success ; but there must be a working criterion as a corrective of debased taste. Fitness for purpose, which Socrates identified with the beautiful, works better than any other. Let your reviewer take as a test case shop-front lettering, incised in stone, inscribed on fasciae or wrought in metal, and let him be credited with perception and liberally educated taste. Then let him study the lettering up and down Regent Street or Tottenham Court Road. He will confess that, though he may not find perfection, the clearest legibility, the most scrupulous respect for material and cleanliness, and the most alive consideration of the tools or machine employed do produce the most attractive design.

C. H. COLLINS BAKER.

ROAD TRAFFIC PROBLEMS.

Nothing in Colonel O'Gorman's lecture roused my "ire," though some things amused me. And my short note about it was not intentionally concerned with "compulsion" or with "speeds," only with what makes a *real percentage*. The Colonel says that "his" percentages were really official ones issued by the Ministry of Transport. If so, all the more pity—both that any Ministry should publish such figures as real percentages, and that they should be accepted by men of Colonel O'Gorman's calibre.

L. W. LYDE.

GENERAL NOTES.

NATURAL HISTORY MUSEUM, S. KENSINGTON: Experiments in tropical lighting for animal groups.—The trustees of the Natural History Museum at South Kensington recently decided to test by experiment the utilisation of some of the huge recesses inside the main hall as show cases, in which exhibits might be placed in surroundings approximating to natural conditions. As an experiment three small elephants were selected to form an exhibit for one of the large recesses arranged among grasses, trees and foliage actually imported from the native haunts of the elephant. The scene was designed and the scenery painted by Captain J. G. Dollman, and the whole of the work was carried out under his supervision. The lighting of the group was entrusted to Dr. G. F. Herbert Smith, who, in conjunction with the Illuminating Engineering Department of the General Electric Co., Ltd., designed a lighting scheme to incorporate changes ranging from brilliant sunshine to ghostly moonlight. Special reflectors and appropriate colour screens are used to produce the effects. Dr. Herbert Smith has also designed a most effective internal structure which enables the whole of the equipment to be reached for re-lamping, or for manœuvring the scenes when required.

INTERNATIONAL EXHIBITION OF HEAVY INDUSTRIES, SCIENCES AND APPLIANCES AT LIÈGE, 1930.—In connection with the Centenary celebrations of the Independence of Belgium in 1930, an International Exhibition will be held at Liège which will include Heavy Industries (Mines, Metallurgy, Mechanics, Electricity, Chemical

Industries, etc), Transport, Civil Engineering, Agricultural Exhibits, and Athletic Competitions. There will also be various supplementary features, viz., an Exhibition of Ancient Walloon Art and International Exhibitions of Music, of Agricultural Machinery, and of various aspects of Agriculture. The "Palais de la Femme" will be devoted to an exhibition of the activities and needs of women and an extensive programme of Congresses and Conferences is under consideration.

Further information can be obtained from the Exhibition Offices, 4, Place Saint-Lambert, Liège.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

- MONDAY JANUARY 23.** Architects, Royal Institute of British, 9, Conduit Street, W. 8.30 p.m. President's Address to Students.
Electrical Engineers, Institution of, Savoy Place, W.C. 7 p.m.
Geographical Society, at 135, New Bond Street, W. 8.30 p.m. Captain C. J. Morris, "Some Valleys and Glaciers of Hunza."
Mechanical Engineers, Institution of, Storey's Gate, S.W. 6.30 p.m. Mr. C. G. Bainbridge, "Cutting Steel and Iron with Oxygen."
University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Prince D. S. Mirsky, "The Russian Novel after 1880." (Lecture II.)
At University College, Gower Street, W.C. 2 p.m. Prof. H. E. Butler, "Virgil and the Epic of Rome," 4.15 p.m. Prof. Brandin, "La mise en scène dans le Théâtre du Moyen Age."
- TUESDAY, JANUARY 24.** Anthropological Institute, 52, Upper Bedford Place, W.C. 8.30 p.m. Anniversary Meeting. Presidential Address by Mr. H. J. E. Peake.
Birkbeck College Chemical Society, Brems Buildings, Fetter Lane, E.C. 5.45 p.m. Dr. N. V. Sidgwick, "Variable Valency."
Civil Engineers, Institution of, Great George Street, S.W. 6 p.m.
Illuminating Engineering Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 6.30 p.m. Discussion on various Problems in Illuminating Engineering.
Photographic Society, 35, Russell Square, W.C. 7 p.m. Captain G. I. Finch, "Mountaineering Photography."
Quekett Microscopical Club, 11, Chandos Street, W. 7.30 p.m. Special Exhibition of Opaque Objects under various Methods of Illumination.
Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Mr. P. R. Coursey, "Dielectrics for Electrical Condensers." (Lecture II.)
University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Sir Bernard Pares, "Russian History from Peter the Great to 1861." (Lecture I.)
At King's College, Strand, W.C. 5 p.m. Dr. J. A. Hewitt, "Integration in the Nervous System." (Lecture II.)
- WEDNESDAY, JANUARY 25.** Geological Society, Burlington House, W. 5.30 p.m. Prof. Dr. J. K. Charlesworth, "The Glacial Retreat from Central and Southern Ireland."
Public Health, Royal Institute of, 37, Russell Square, W.C. 4.30 p.m. Dr. Godfrey Carter, "Tests for Drunkenness, particularly in relation to Motor Accidents."
University of London, at King's College, Strand, W.C. 5.30 p.m. Mr. Henry Wickham Steed, "The Prelude to the War." (Lecture II.)
At the School of Oriental Studies, Finsbury Circus, E.C. 5.15 p.m. Sir Wolsley Haig, "Two English Writers on Persia."
- At University College, Gower Street, W.C. 3 p.m. Signor Camillo Pellizzi, "La Linea del Paradiso," 4 p.m. Prof. A. V. Hill, "Muscle." (Lecture II.) 5.30 p.m. Mr. J. H. Helweg, "Georg Brandes." (Lecture II.)
- THURSDAY, JANUARY 26.** Aeronautical Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 6.30 p.m. Messrs. R. J. Mitchell and P. A. Ralli, and Captain G. S. Wilkinson, "Schneider Trophy Machine Design."
Royal Society, Burlington House, W. 4.30 p.m.
Royal Institution, 21 Albemarle Street, W. 5.15 p.m. Prof. J. F. Thorpe, "Unsaturation of Carbon Compounds."
University of London, at Bedford College for Women, Regents Park, N.W. 5.15 p.m. Prof. Dr. Percy Buck, "The Meaning of Music."
At the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Lady Muir, "Bulgaria from the Liberation to the Balkan Wars, 1878-1912." (Lecture I.)
At King's College, Strand, W.C. 5.30 p.m. Dr. F. W. Rogers Brambell, "The Development of Sex, with special reference to recent work on Birds and Amphibians." (Lecture II.)
At the London School of Economics, Houghton Street, W.C. 5 p.m. Dr. H. Finer, "The Civil Service and Parliament."
At University College, Gower Street, W.C. 5 p.m. Dr. R. J. Ludford, "Cytology in relation to Physiological Processes." (Lecture II.) 5.15 p.m. Prof. J. E. G. de Montmorency, "Customary Law in the British Empire, Asia and the Pacific." (Lecture I.)
Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Mr. Philip B. James, "The Art of Bookbinding."
- FRIDAY, JANUARY 27.** Mechanical Engineers, Institution of, Storey's Gate, S.W. 7 p.m. Mr. C. H. Fairis, "Applications of Electro-Chemical Deposits of Metals to Engineering Purposes."
Metals, Institute of, at the University, St. George's Square, Sheffield. 7.30 p.m. Conjoint Meeting with kindred Societies. All-Metal Aeroplane Lecture.
Midwives' Institute, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 6 p.m.
North-East Coast Institution of Engineers and Shipbuilders, at the Mining Institute, Newcastle-upon-Tyne. 6 p.m. Mr. J. Lockwood Taylor, "Ship Vibration Periods."
Physical Society, at the Imperial College of Science and Technology, South Kensington, S.W. 5 p.m.
Royal Institution, 21, Albemarle Street, W. 9 p.m. Miss D. A. E. Garrod, "Prehistoric Cave Art."
University of London, at King's College, Strand, W.C. 5.30 p.m. Mr. Hilary Jenkinson, "English Seals, Mediæval and Modern."
At University College, Gower Street, W.C. 5 p.m. Mr. C. F. A. Pantin, "Comparative Physiology." (Lecture III.)
- SATURDAY, JANUARY 28.** L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Mr. H. N. Milligan, "Proofs of Evolution in Animals and Man."
Royal Institution, 21, Albemarle Street, W. 3 p.m. Prof. R. W. Chambers, "Some Tudor Biographers."

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.(2.)

NOTICES.

NEXT WEEK.

MONDAY, JANUARY 30th, at 8 p.m. (Cantor Lecture.) ALBERT ERNEST DUNSTAN, D.Sc., F.I.C., F.C.S., "The Scientific Foundation of the Refining of Petroleum." (Lecture III.)

TUESDAY, JANUARY 31st, at 4.30 p.m. (Dominions and Colonies Section.) THE RIGHT HON. LORD LOVAT, K.T., K.C.M.G., K.C.V.O., C.B., D.S.O., "Migration in the Empire." THE RIGHT HON. THE EARL OF CLARENDON, P.C., G.C.B., G.C.V.O., will preside. Tea will be served in the library at 4 o'clock, before the meeting.

WEDNESDAY, FEBRUARY 1st, at 8 p.m. (Ordinary Meeting.) CHARLES HERBERT WRIGHT, B.A., "Modern Aspects of Rubber Cultivation." SIR DAVID PRAIN, C.M.G., C.I.E., M.B., LL.D., F.R.S., will preside.

CANTOR LECTURES.

MONDAY, JANUARY 16th, 1928. DR. ALBERT ERNEST DUNSTAN, D.Sc., F.I.C., F.C.S., delivered the first of his course of these lectures on "The Scientific Foundation of the Refining of Petroleum." The lectures will be published in the *Journal* during the summer recess.

EIGHTH ORDINARY MEETING.

WEDNESDAY, JANUARY 18th, 1928. PROFESSOR A. E. RICHARDSON, F.R.I.B.A., Professor of Architecture, University College, London, in the Chair. A paper on "Methods of Radiant Heating" was read by MR. ARTHUR HENRY BARKER, B.Sc., B.A., M.I.E.E., Wh.Sch. The paper and discussion will be published in the *Journal* on February 24th.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES

ALLOY STEELS, THEIR MANUFACTURE, PROPERTIES, AND USES.

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LECTURE I.—GENERAL.

(Delivered November 14th 1927.)

HISTORICAL INTRODUCTION.

Until about 70 years ago wrought iron was the principal "constructional" metal at the disposal of the engineer. It possessed elasticity, mechanical strength, ductility, malleability, toughness, and some resistance to corrosion in the atmosphere. It was used for a great variety of purposes—rods, tubes, sheets, plates, girders, rails, bridges, boilers and ships. Essentially it was commercially pure iron and in particular it did not contain, apart from slag, more than a small amount either of carbon or of any other element. Steel of course had long been known, made either by the cementation or crucible process. It might contain anything from about 0.5 to 1.5 per cent. of carbon, the effect of which was to harden the iron. This hardness could be still further increased by quenching in water from temperatures above 750°C. The steels of that period were used almost entirely in the form of tools. Owing to their cutting hardness they were used for machining the much softer wrought irons used for engineering purposes.

The advent of Bessemer steel and Siemens steel about 70 years ago placed in the hands of the engineer new and more varied constructional materials. The steels produced by these processes were softer than tool steels, and, in fact, some of them were quite as soft as wrought iron. It was possible, however, to control the degree of hardness by regulating the percentage of carbon. Such steels could be produced in large masses and their working up into finished products involved a new technique. Whereas wrought iron could only be built up into large pieces by welding together several smaller pieces, steels made by the Bessemer and Siemens processes were produced from large ingots weighing many tons which were reduced by mechanical work to the appropriate size and form. In the course of time carbon steels, with a great variety of properties, became available, and the range of properties was still further increased by careful heat-treatments to which most of them were susceptible.

It did not take long for these discoveries to affect the position of wrought iron as a constructional material, and gradually steels have displaced it from its exclusive position. For certain purposes it still holds its own and something

like 1,000,000 tons are manufactured annually even at the present time. As against this, the annual production of steel is of the order of 80,000,000 tons, and as a constructional material it has replaced wrought iron for all except certain special purposes. Two factors have brought this about. The first is that wrought iron is a comparatively soft material, whereas the hardness and other properties of carbon steels can be varied to a great extent by varying the percentage of carbon. The second is that, speaking broadly, the properties of wrought iron are unaffected by heat treatment, whereas those of all steels containing above about 0.35 per cent. of carbon can be varied to a great extent. For many years, therefore, the heat treatment of steels was carefully studied. In the early days knowledge had to be acquired more or less empirically. The birth and development of metallography, however, about 40 years ago changed all this, and from about 1890 onwards, it has been possible to study the heat treatment of any steel in a scientific manner.

The most important property of steel, so far as heat-treatment is concerned, is its capacity—so long as the carbon exceeds about 0.35 per cent.—to be hardened by quenching in water from above 750°C . Provided the chilling is sufficiently quick, the hardness of steels can be increased about six times by this process. After hardening, the steel is brittle and requires to be toughened by tempering, i.e., by heating to a particular degree of temperature between 200° and 350°C . According to the temperature used the degree of softening can be adjusted. In this way hardened and tempered steels can be produced and used for a great variety of purposes. It is obvious that this process depends for its success upon the capacity to withdraw heat from the steel by chilling at a sufficiently rapid rate. There is no difficulty about doing this for thin sections, e.g., knives, and in fact tools up to two inches diameter can be properly hardened in this way. It is, however, not possible to withdraw heat sufficiently rapidly at 750°C . from a thick mass of steel to enable it to be hardened, and, therefore, the hardening of such a mass cannot be accomplished by quenching. It can, however, be effected in another way, viz., by a change in composition produced by adding an alloying element—nearly always a metal.

An alloy steel is one which contains one or more elements other than carbon, in sufficient proportion to modify and improve substantially some of its useful properties. It is necessary to include the qualification "in sufficient proportion" in the above definition, because elements other than carbon may be added to steel for quite another reason:—viz., to give the desired composition and to cure some ill or defect to which the final product might otherwise be liable. The two purposes may be illustrated from the case of manganese. In all steel made by the Bessemer and Open-hearth Processes, it is necessary to have present a certain quantity of manganese, usually not exceeding 1.5 per cent. to remove the oxygen. Otherwise the steel is red short and cannot be rolled. The resulting product, however, is not an alloy steel but simply a carbon steel. A much larger amount is required to make commercial Manganese

steel, which should contain from 11 to 14 per cent. of manganese, and this is a true alloy steel.

It is probable that the first useful alloy steel made was Mushet's self-hardening tungsten tool steel, patented in 1868. As the name indicates, this steel did not require water quenching to enable it to be hardened. In virtue of the tungsten and manganese which it contained it was hardened by merely cooling in air. This was the first case of the hardening of steel simply by a change in composition, and Mushet was the first man to prepare a steel cutting tool which did not require quenching in a liquid. About 15 years later two other alloy steels were successfully produced. The one contained chromium and was used for the manufacture of stamp shoes and dies in pulverising ores of gold and silver, and solid shot for piercing armour. The other contained manganese and has come to be known as Hadfield's manganese steel. This is one of the most remarkable alloys ever produced. It was the first of a new class of steel with properties different from any which could be obtained by heat-treated carbon steel. Nickel steel was chronologically the fourth alloy steel to be introduced, mainly for structural purposes. This occurred towards the end of the last century. In 1900 came the Taylor-White process of heat-treating tungsten-chromium steels which thus became the first high-speed cutting tools. These materials created a revolution in workshop practice. Not merely did they cut at temperatures far above that at which the carbon tool loses its hardness, but they also did not achieve their maximum cutting properties until temperatures were reached in the neighbourhood of from 600° to 700°C., i.e., a red heat. Accordingly they were said to possess the property of "red hardness." Great progress in the manufacture of these steels has taken place.

Since the beginning of the present century, the development of alloy steels has been almost continuous. Most elements, which can be procured in sufficient quantity, have been alloyed with iron in various proportions either alone or in combination with others in the search for useful steels. Some of them had an ephemeral life which would have been doubtless prolonged had not some other more satisfactory steel been developed. At the present time it is not too much to say that alloy steels have brought about a series of revolutions in various industrial fields in which steel plays an important part—in particular for (1) constructional, (2) cutting, and (3) electrical purposes. The object of this course of lectures is to give a survey of the most important steels in use at the present time, and to indicate the wide and varied range of properties which can now be obtained by correct composition and heat-treatment. With few exceptions all alloy steels are heat-treated for use, in order to develop in them the highest physical properties which they are capable of possessing. As Mr. H. D. Hibbard† has pointed out in a valuable monograph on alloy steel

†H. D. Hibbard, "Manufacture and Uses of Alloy Steels." John Wiley and Sons, Inc., New York, 1919.

"Developments in the manufacture of alloy steels and in heat-treatment of steel have occurred simultaneously during the past 40 years, and care is needed lest the benefits gained from the one be confounded with those afforded by the other. The highest merit is obtained from the adoption of both methods together—that is the use of heat-treated alloy steels."

STATISTICS OF PRODUCTION.

So far as I have been able to ascertain, with the exception of the United States of America, no country publishes particulars of its production of alloy steels. It is therefore impossible to state what the world's production is at the present time. It appears from the annual statistical report of the American Iron and Steel Institute, 1925, p.28, that during that year—the latest for which complete figures are available—no less than 2,432,973 tons of ingots and castings were made in that country. The following table shows the production according to processes.

TABLE I.
PRODUCTION OF ALLOY STEEL INGOTS AND CASTINGS.
BY PROCESSES. GROSS TONS. 1925.

<i>Processes.</i>	<i>Ingots.</i>	<i>Castings.</i>	<i>Total.</i>	<i>%</i>
Open-Hearth Steel (basic) ..	1,935,676	6,729	1,942,405	80.0
Open-Hearth Steel (acid) ..	60,959	46,135	107,094	4.4
Bessemer Steel	67,774	14,703	82,477	3.3
Crucible Steel. . . .	6,607	610	7,217	0.3
Electric Steel	249,374	44,406	293,780	12.0
	2,320,390	112,583	2,432,973	100.0

The figures show that by far the greater part of the alloy steel manufactured is used in the form of wrought material (95 per cent. of the total). It is also clear that 80 per cent. is now made in the basic open-hearth furnace. Electric steel is responsible for 12 per cent., acid open-hearth for 4.4 per cent., and Bessemer for 3.3 per cent. It is interesting to notice that crucible steel is responsible for only 7217 tons (0.3 per cent.). In all probability the steels made by this process were tungsten steels. These figures show that an important change in the methods of manufacture has taken place since the early days of alloy steel production. Originally all such steels were made in crucibles even when large ingots were required. When the Iron and Steel Institute visited Düsseldorf in the autumn of 1902, one of the metallurgical displays was that given by Krupps, who cast an 80-ton armour plate of nickel-chromium steel by the crucible process. The contents of no less than 1600 crucibles were required, each of which held about 1 cwt. of metal. The furnaces containing the crucibles were ranged round the casting pit. At a given signal the first crucibles were taken out, the lids prized open, the supernatant slag removed

by skimming, and the metal then poured into the casting pit. The contents of other crucibles were then similarly dealt with. The procedure was so organised that in 17 minutes the contents of the 1600 crucibles had been poured, corresponding to a rate of 94 per minute. Such steel is now made either in the open-hearth or the electric furnace on a large scale. The Bessemer process does not permit of the same degree of control of composition as does the open-hearth or electric process, and it is not surprising that the amount of steel made in this way is comparatively small. With few exceptions the only steels made in the crucible to-day are tungsten steels.

Since the production of alloy steel in the United States of America was nearly $2\frac{1}{2}$ million tons in 1925 it is fairly safe to conclude that the world's production for the year in question will not have fallen short of 4 million tons. This allows only $1\frac{1}{2}$ million tons for the whole of the world except America, and is probably well within the mark. It is clear therefore that the alloy steel industry is of considerable magnitude and far exceeds that of any other metal except carbon steel itself.

PRINCIPAL ALLOYING METALS USED.

It is somewhat remarkable to find that in spite of the large number of metals available, comparatively few have proved themselves suitable for the manufacture of alloy steels. It is not suggested that finality has been reached in this respect, and there is little doubt that, with the progress of investigations, a greater number of metals will be used in the course of time than is at present the case. It is, however, significant that by far the greater number of alloy steels which have proved themselves the most suitable for particular purposes are composed of one or more of only seven alloy metals. A study of these reveals some interesting facts which are brought out in the sub-joined table.

TABLE II.
METALS USED IN MAKING "ALLOY STEELS" AND SOME OF THEIR PROPERTIES.

1	2	3	4	5	6
<i>Metal.</i>	<i>Group No</i>	<i>Atomic No.</i>	<i>Atomic Weight.</i>	<i>Melting Point °C.</i>	<i>Crystal Lattice.</i>
Vanadium ..	V A	23	51.0	1720°	Body-centred cube
Chromium ..	VI A	24	52.0	1525°	" " "
Manganese ..	VII A	25	54.93	1260°	" ? "
Iron ..	VIII	26	55.84	1535°	Body-centred Cube.
Cobalt ..	VIII	27	58.97	1478°	Face-centred cube.
Nickel ..	VIII	28	58.68	1452°	" " "
Molybdenum ..	VI A	42	96.0	2450°	Body-centred cube.
Tungsten ..	VI A	74	184.0	3267°	" " "

The metals in question are Vanadium, Chromium, Manganese, Cobalt, Nickel, Molybdenum and Tungsten. As will be seen from the second column, all of them are group A metals, (periodic system) with the exception of cobalt and nickel which occur in the same group as iron itself (VIII). Column 3 shows that three of them—vanadium, chromium and manganese—occur immediately before iron in the system and thus have the three immediately preceding atomic numbers, viz., 23, 24, and 25, that of iron being 26. Cobalt and nickel which follow, have the immediately succeeding atomic numbers 27 and 28. Five out of the seven metals, therefore, are the immediate companions of iron in the periodic system. The remaining two metals, molybdenum and tungsten, are homologues of chromium. Each of them occurs in group VI.A. Column 4 shows that the atomic weights of the first five alloying elements are very near that of iron, while column 5 demonstrates that all of them melt at a high temperature. Iron melts at about $1535^{\circ}\text{C}.$, and with the exception of manganese, the remaining metals all melt above $1450^{\circ}\text{C}.$, while two of them, molybdenum and tungsten, are among the highest melting metals known. Column 6 giving the crystal symmetry shows that with the possible exception of manganese, each of the alloying metals crystallises in the cubic system and of these, four crystallise in precisely the same sub-division as iron itself, viz., the body-centred cube, while the remaining two crystallise in the face-centred cube. It may, therefore, be concluded from these facts that the capacity to form alloy steels has hitherto been found to be confined to a small number of metals adjacent to iron in the periodic system which are high-melting, and possess a very similar degree of crystal symmetry. These properties undoubtedly make for good miscibility of the metal or metals in question with iron, and there is little doubt that the capacity to form a useful alloy steel is bound up with this property.

One other element, silicon, a non-metal and chemical homologue of carbon forms steels which are generally classified as alloy steels. It is doubtful, however, whether this is a sound method of classification. A brief account of silicon steels will be found in Lecture IV.

The simplest possible alloy steel is what is called a Ternary steel. It contains three elements, iron, carbon, and the alloying element in question. Tungsten, chromium, manganese, and nickel steels fall into this class. In many cases, however, two alloying metals are present and in this case the steel is known as a Quaternary steel. Well known steels of this type are the nickel-chromium, chromium-vanadium and chromium-tungsten steels. There still remain, however, a number of steels which are even more complex and contain, three, four, or even five alloying metals. These are generally classified under the head of Complex steels. Examples of these are found among the high-speed cutting tools which may contain, chromium, tungsten, vanadium, cobalt, and molybdenum and the heat-resisting steels which may contain chromium, nickel, tungsten and silicon.

THE EFFECT OF ALLOYING METALS ON THE INVERSIONS OF STEELS.

Before considering the manufacture and properties of alloy steels, it is necessary to have as clear an idea as possible of the effect produced when an alloying element is added to steel. We must begin with iron itself. This metal exists in no less than four forms, each of which has a definite temperature range of stability and specific properties associated with it. These are shown in the following table.

TABLE III.

<i>Variety of Iron.</i>	<i>Temperature Range of Stability. ° C.</i>	<i>Crystal Form.</i>
δ	1535°-1400°	Body-centred cube.
γ	1400°- 900°	Face-centred cube.
β	900°- 768°	Body-centred cube.
α	768°- 0°	Body-centred cube.

When we pass from one variety of iron to another there is a change of energy which manifests itself in the form of an evolution of heat on cooling and an absorption of heat on heating. These phenomena are well brought out in the so-called cooling curves and heating curves. Fig. 1 shows a cooling curve of iron in which the evolutions of heat are shown by the breaks in the curve.

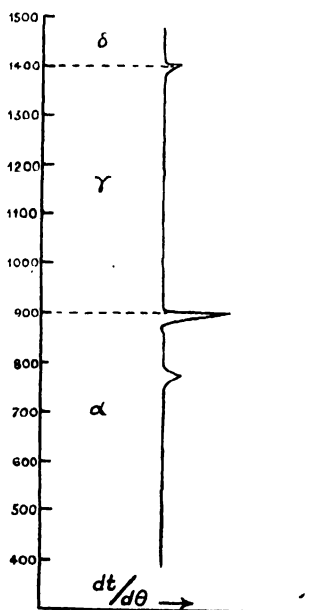


FIG. 1.—Inverse-Rate Cooling Curve of Pure Iron.

It will be seen that these are not all alike. The changes from delta to gamma and from beta to alpha are indicated by small breaks in the curve, whereas that from gamma to beta is much larger. Two of the evolutions of heat are accompanied by changes of crystal form, viz., at 1400°C. from the body-centred to the face-centred cube and at 900°C. from the face-centred back to the body-centred cube. (The body-centred cube has 9 atoms, one at each corner of the cube and one in the centre; the face-centred cube has 14 atoms, one at each corner of the cube and one in the centre of each face). The evolution of heat at 768°C. , however, is not associated with any change of crystal form but mainly with the appearance of magnetism in the iron on cooling. (Strictly speaking what happens here is that the magnetic permeability of the iron undergoes a rapid increase). From the phase standpoint therefore beta and alpha iron are the same form of iron. It will be seen therefore that delta, beta and alpha irons, each have the same crystal form (a body-centred cube) and that gamma iron is the exception in having a face-centred cube. This change of crystal form is not merely of scientific interest but has most important practical consequences since gamma iron can dissolve far more carbon than any of the other varieties and the hardening of steel by quenching is due to the capacity of the steel to retain this carbon forcibly dissolved even at the ordinary temperature. The temperatures at which one variety of iron passes into another on cooling or heating are known as temperatures of the *inversion* in question.

When carbon is added to iron, and steel is produced, striking effects are observed on the inversions in the iron and a new inversion makes its appearance. These results can best be expressed in the form of the equilibrium diagram

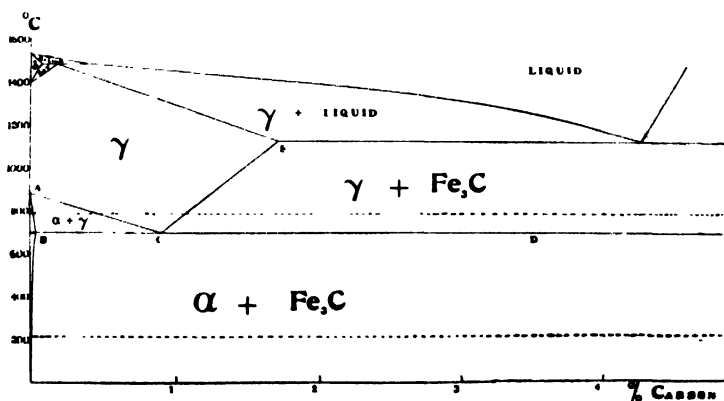


FIG. 2.—The Iron-Carbon Equilibrium.

which is now well known and is reproduced in Fig. 2. The co-ordinates of this diagram are temperature and concentration, and the diagram itself shows the constituent or constituents which is or are present at any given temperature

for any particular concentration of carbon under conditions of equilibrium. For the present purposes all that it is necessary to do is to emphasise the following points. Leaving out of consideration the effect of carbon on the delta to gamma change at $1400^{\circ}\text{C}.$, which is above the temperature used in heat treating steels, it lowers the temperature of the gamma to beta/alpha inversion from 900° to $700^{\circ}\text{C}.$ The concentration of dissolved carbon has then reached 0.9 per cent., and at this temperature and concentration a new reaction makes its appearance. Below this point gamma iron cannot exist as a stable phase and the solid solution inverts to alpha iron containing no carbon plus carbide of iron containing all the carbon as Fe_3C . If we are dealing with an alloy containing exactly 0.9 per cent. of carbon, then the whole of the solid solution passes at this temperature into the characteristic mixture of alpha iron and carbide known as pearlite, a mechanical mixture of the two phases in a fine state of sub-division. At ordinary rates of cooling the mixture known as an eutectoid arranges itself in the form of alternate plates of iron and iron carbide. Any steel containing less than 0.9 per cent. of carbon undergoes the same reaction at this temperature, but contains an excess of alpha iron which has previously separated at another temperature corresponding to its composition.

This mixture of iron and iron carbide obtained by cooling a 0.9 per cent. carbon steel at ordinary rates while harder than iron, is still comparatively soft. If, however, it is rapidly chilled by quenching in water from about $750^{\circ}\text{C}.$, the formation of iron carbide is prevented, although it is not possible completely to prevent the gamma iron from passing to alpha iron. There has been much controversy as to the precise nature of this product, but it is I think generally accepted now that it contains very minute crystals of alpha iron formed under the rapid conditions of chilling which prevent crystal growth together with carbon principally in a state of enforced solution in alpha iron. This is the so-called Martensite, the constituent of hardened steel. If rates of cooling are adopted intermediate between what has been called ordinary cooling and quenching, other structures are obtained but constitutionally the products do not differ from the constituents of pearlite, viz., alpha iron and iron carbide. They differ only in their size and probably in their crystal form.

No one has yet succeeded in chilling a 0.9% carbon steel from $750^{\circ}\text{C}.$ so rapidly that the gamma to alpha change is also completely prevented, although it should be possible to do so. But it can be and has been achieved by making alloy steels of a suitable composition (see page 264), and therefore it is justifiable to construct the following table showing the structures of an 0.9% carbon steel according to whether (1) the gamma to alpha change and the carbide formation have been completely prevented, (2) the gamma to alpha change has occurred but the carbide formation has been prevented, and (3) both the gamma to alpha change and the carbide formation have taken place.

TABLE IV.

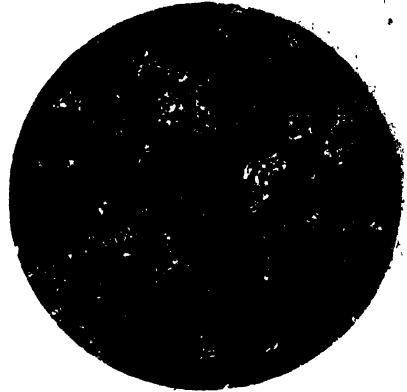
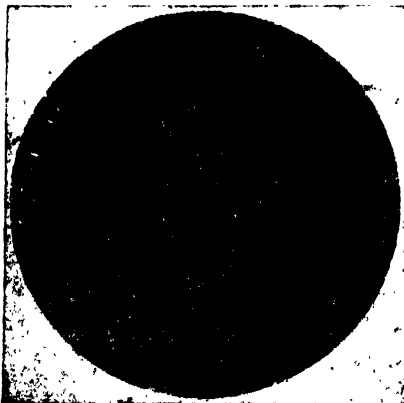
STRUCTURES OBTAINED IN A 0.9% CARBON STEEL BY COOLING AT DIFFERENT RATES.

<i>Rate.</i>	<i>Structure.</i>	<i>Change.</i>	<i>Figure.</i>
Most rapid chilling possible.	Austenite.*	None.	3
Rapid chilling.	Martensite.	Gamma to alpha change only	4
Slower chilling.	Troostite.	Gamma to alpha change + carbide formation.	5
Still slower chilling.	Sorbite.	Gamma to alpha change + carbide formation.	6
Cooling at ordinary rates.	Pearlite.	Gamma to alpha change + carbide formation.	7

The next aspect to be considered is the influence of the rate of cooling upon the temperature at which the inversion takes place. As already explained, at ordinary rates of cooling the solid solution of carbon in gamma iron, containing 0.9% of carbon, inverts to a mixture of alpha iron and cementite. The temperature observed is about 715°C. when due precautions are taken to avoid super-cooling. The rate of cooling required to produce Sorbite is such as to cause a slight lowering of the temperature of the inversion, probably to about 700°C. In other words, super-cooling of about 15° takes place. The effect of the accelerated rate of cooling is to retard crystal growth in the precipitated alpha iron and cementite to such an extent that the separate crystals cannot be seen with any distinctness, and on etching a specimen containing sorbite only a faint granulation is observable. With still quicker cooling so as to produce the constituent Troostite the temperature of the inversion is lowered from 715° to from 670° to 630°C., i.e., a lowering of from 45° to 85° takes place. The mixture of alpha iron and cementite is in this case precipitated in so fine a condition that the latter is decomposed by the etching reagent and thus gives a dark appearance due to the precipitation of carbon. The complex is so fine that it may almost be regarded as an emulsion.

With the rapid rate of chilling required to produce Martensite, a large fall in the temperature of the inversion is produced. The reaction does not begin till about 300°C., i.e., there is a lowering of about 400°C. Moreover, it occurs over a prolonged range of temperature and is probably not complete by the time that the ordinary temperature is reached. It is to be noted therefore that although troostite and martensite represent successive stages in the quenching of steel there is an interval of at least 350°C. between the temperatures at which they are produced. In the case of martensite formation only the gamma to alpha iron change takes place, and even so it is incomplete. This iron is precipitated in certain crystal planes of the rapidly chilled and rigid

* This has not been completely realised. Mixtures of Austenite and Martensite are obtained by this procedure.

FIG 3.—Austenite $\times 200$.FIG 4 —Martensite $\times 400$.FIG. 5. Troostite $\times 200$ FIG. 6.—Sorbite $\times 400$,FIG. 7.—Pearlite $\times 400$.

Micro-structure of Steels.

gamma iron, and it is now established that the crystals are very small. They have had no opportunity of growth. These results show that the different structures obtained in carbon steels by cooling at different rates are accompanied by changes in the temperature at which the inversion takes place. The quicker the rate of cooling the lower the temperature at which the inversion takes place. Moreover, as just shown the fall in the temperature of the inversion is not gradual but exhibits a large discontinuity between troostite and martensite. If a steel contains martensite, i.e., is in the fully hardened condition, it may be softened within certain limits to any required extent by gradually heating it. The softening begins at about $200^{\circ}\text{C}.$, and proceeds further the higher the temperature used. It is accompanied by a precipitation of carbide of iron from the super-cooled matrix, together with a coalescence and growth of the crystals of alpha iron.

Hitherto only the cooling of carbon steels has been considered. If the process is reversed and a steel is heated from the ordinary temperature, the reverse reaction takes place. A 0.9% carbon steel containing a mixture of alpha iron and cementite when heated to rather above the temperature of the inversion on cooling, passes into gamma iron containing the whole of the carbon dissolved, i.e., Austenite. The actual temperature is about $730^{\circ}\text{C}.$, i.e., about 15° above the temperature on cooling. There is thus a slight hysteresis, but it is so small that this reaction is usually regarded as reversible. The degree of hysteresis depends to some extent upon the size of the particles of alpha iron and cementite, and is the greater the larger they are. If the steel which is being heated contains less than 0.9% of carbon then at $730^{\circ}\text{C}.$ the mixture of alpha iron and cementite in the eutectoid proportion dissolves forming austenite, and as the temperature is raised the excess of alpha iron gradually dissolves in it.

The foregoing is a brief account of the physico-chemical changes which take place when steels are heat-treated. They all depend upon the existence of the different forms of iron described, their differing capacities for dissolving carbon, and the extent to which reaction taking place under equilibrium conditions can be affected by varying the rate of cooling. In particular it is the great solvent capacity for carbon of gamma iron and the almost complete insolubility of carbon in alpha iron that renders possible the great variety of properties obtained in heat treated steels. One other fact should also be mentioned at this point, viz., that the quenching of carbon steels, while it thus permits of the production of valuable properties, is accompanied by strains set up in the metal due to quenching. It is well known, e.g., that in the hardening of tool steel, the greatest care is required to quench in the proper manner, otherwise cracks form due to the release of strains in the tool.

We next have to consider briefly what is the effect of alloying metals on the inversions of steels. Since the majority of alloy steels contain less than 0.9% of carbon, we can confine the discussion to steels of such composition,

and can consider the effect on the gamma to alpha change (known as Ar_3) and the gamma to alpha change plus carbide formation (known as Ar_1). (In this discussion beta iron can be left out of consideration. As already mentioned, from the point of view of phases beta and alpha iron are identical). Alloy steels, as already stated are ternary, quaternary or more complex alloys, and the logical method of examination of their constitution would be by means of equilibrium diagrams, such as that of iron and carbon previously described. A serious difficulty, however, is at once encountered. It is very much more difficult to determine the equilibrium diagram of a ternary than a binary system. It is in any case a much longer operation since the number of alloys that require to be investigated is very much larger. This, however, is not the main difficulty. The real difficulty is that so far it has proved impossible to establish perfect physico-chemical equilibrium conditions in these systems. Whereas, therefore, the equilibrium diagram of a binary system such as iron and carbon is now well established in its essential features, no equilibrium diagram of any ternary steel, and still less any quaternary or more complex steel, is yet known with anything like the same degree of precision.

In the great majority of cases, when an alloying metal is added to a carbon steel it has two effects on its inversion points, (1) it displaces and usually lowers the equilibrium transformation temperature or inversion, and (2) it increases the hysteresis effect which is only slightly present in carbon steels. There is also a further complication. The temperature of inversion in an iron-carbon steel is hardly affected by the original temperature from which it is cooled, provided the rate of cooling when the inversion temperature is reached, is sufficiently slow to allow it to take place. This is by no means the case with alloy steels. In many cases the temperatures of the inversions depend to a marked extent upon the temperature from which cooling begins, and this is conspicuously the case with tungsten, molybdenum, tungsten-chromium and molybdenum-chromium steels.

As an illustration of the influence of an alloying metal on the principal (Ar_1) change in a medium carbon steel, I will take the case of the metal nickel. The following results, given in Table V were obtained by Sir Robert Hadfield, Mr. Longmuir and myself, and published in the Seventh Report to the Alloys Research Committee of the Institution of Mechanical Engineers 22 years ago.

The inversion in the pure iron carbon alloy occurred sharply at 690°C . About 1% of manganese was added so as to obtain a forgeable series of alloys and this caused a lowering of 25° . Here also the change was sharply defined. The addition of 1% of nickel produced a further lowering of 16° , while that of 2% caused a total lowering of 49° . At 4.25% the lowering was about 100° and was spread over an appreciable interval of temperature in contrast to the two previous alloys. At 4.95% the total lowering was 152° and the change itself was spread over nearly 100° since it was not completed until 422° . By

TABLE V.

INFLUENCE OF NICKEL ON THE TEMPERATURE OF THE PRINCIPAL (A_{I_1}) INVERSION IN A MEDIUM CARBON STEEL ON HEATING AND COOLING.

1	2	3	4	5	6
<i>Carbon. Per cent.</i>	<i>Manganese. Per cent.</i>	<i>Nickel. Per cent.</i>	<i>Inversion on Cooling. Degrees Centigrade.</i>	<i>Inversion on Heating. Degrees Centigrade.</i>	<i>Extent of Hysteresis.</i>
0.47	trace	nil	690°	720°	30
0.47	0.95	nil	665°	709°	34
0.48	0.79	1.20	649°	700°	51
0.44	0.83	2.15	616°	664°	48
0.40	0.82	4.25	561°-544°	634°	73
0.42	1.03	4.95	513°-422°	634°	121
0.52	0.92	6.42	171°-125°	622°	451
0.43	0.79	7.95	156°-123°	586°	430
0.41	0.85	12.22	100°-78°	586°	486
0.45	0.83	15.98	48°-?	586°	over 500
0.41	0.96	19.91	absent		—

far the most striking lowering was produced at 6.42%, i.e., the inversion was lowered by a further 342°C. It did not begin until 171° and was not complete until 125°. At about 7.95% of nickel the temperature was hardly further altered, while at 12% it had fallen below 100°C., corresponding to a total fall of nearly 600°C. The addition of 15.98 per cent. lowered the inversion to about 48°. In the last alloy of the series no thermal arrest was observed. This is due to the fact that sufficient nickel was now present to lower the inversion point below the ordinary temperature. It will be seen, therefore, that in this series of alloys 19.91% of nickel was sufficient to lower the main inversion from 665° to below the ordinary temperature. Moreover, the lowering was not uniform. Up to 5% of nickel it was gradual and approximately uniform. Then came a sudden very marked fall at 6.4% nickel and after this only a slight lowering up to 15.98% nickel.

The results obtained on heating the steels were equally interesting and are given in column 5. It will be seen that whereas the temperatures of the inversion on heating are not greatly different from those on cooling for the earlier members of the series, this is by no means the case for the later members, and that in all cases the main inversion point on heating is comparatively high. In other words, the hysteresis becomes very large in the case of the later members of the series. The actual extent of the hysteresis is shown in column 6. For the first 2% of nickel it is about 50° against 30° in the pure carbon steel. At 5% it is 120°. Between 6% and 12% it is more than 400°. At 16% it is over 500°C. It is clear therefore that this particular series can be divided into

three classes in respect of the degree of lowering of the main inversion point and the extent of hysteresis. Up to 5% of nickel the lowering and the hysteresis are moderate. From 6% to 16% they are very large. At 20% of nickel the inversion point was below the ordinary temperature and the extent of the hysteresis cannot be stated.

Corresponding to this classification from the thermal data into three classes well marked structural differences were found in the alloys. Up to 5% of nickel they were all pearlitic (this includes sorbitic and troostitic), i.e., they had undergone the gamma to alpha change and carbide had been formed. From 6% to 12% they were martensitic, i.e., they had undergone only the gamma to alpha change. The thermal inversion shown here is due to this. The alloy containing 16% was partly martensitic and partly austenitic. It showed a very small thermal change. That containing 20% was exclusively austenitic. This agrees with the fact that no inversions were found in this alloy.

The foregoing experimental results show that the effect of adding nickel in increasing quantities to a carbon steel is exactly the same as chilling it at quicker and quicker rates. The same sequence of structures is obtained and the temperature of the inversion is lowered in the same way in both cases. There is only one difference, in fact, and that is, that by the addition of sufficient nickel (20%) it is possible completely to inhibit the gamma to alpha and carbide formation changes even at ordinary rates of cooling and produce the pure austenitic structure, whereas the most rapid chilling yet devised has not succeeded in preventing a partial occurrence of the gamma to alpha inversion which results in the production of a mixed austenitic and martensitic structure. One other consideration should be mentioned, viz., that the nickel steels containing the various types of structure described are not in the same condition of strain as that produced by the water quenching of carbon steels. This is a manifest advantage.

Not all the elements used in alloy steel manufacture act in the same way as nickel although the majority of them lower the temperature of the inversions and cause a pronounced degree of hysteresis, particularly when they are present in large quantities. This explains why it has not yet been found possible to use the equilibrium diagram as a method of scientifically classifying such steels. Two methods of classification have, however, been adopted, each of which is in the nature of a compromise, and a brief account of these will now be given. *

METHOD I.

According to the first method the transformations are represented by means of dilatation curves on heating (shown in dotted lines) and on cooling (shown in continuous lines). For purposes of simplicity the several periods of trans-

* A full account will be found in "The Introduction of the Study of Metallography and Macrography," by Guillet and Portevin, translated by Taverner, pp. 166 to 197.

formation, which frequently are not individually discernible, are grouped as a single point. Each curve therefore, has only two changes of direction on heating and cooling, the one indicating the beginning and the other the end of the transformation. Below the period of transformation the curve shows the expansion of the steel in the stable condition at ordinary temperatures and above it in the stable condition at high temperatures. The directions of these two portions of the curve do not differ very much. Fig. 11 represents such a curve, the co-ordinates of which are Elongation and Temperature. A.B. represents the stable condition on heating from the ordinary temperature. It corresponds to a regular expansion of the steel. B.C. is the transformation on heating and is accompanied by a contraction. C.D. represents the stable condition on heating above the transformation point. This also is accompanied by an expansion as the temperature rises. The directions of the two lines A.B. and C.D., while not the same, are not very different. D.E. represents the contraction of the steel on cooling from the temperature corresponding to D. E.F. is the transformation on cooling and is shown by an increase in length. F.A. represents the contraction after the completion of the transformation down to the ordinary temperature.

In the case of any given steel, the transformation temperature on cooling depends on the maximum temperature reached, the length of time it is maintained at that temperature, and the rate of cooling. For the purpose of simplicity it will be assumed in the following description that the steels have been heated for equal periods of time at the same temperature ($950^{\circ}\text{C}.$), and at

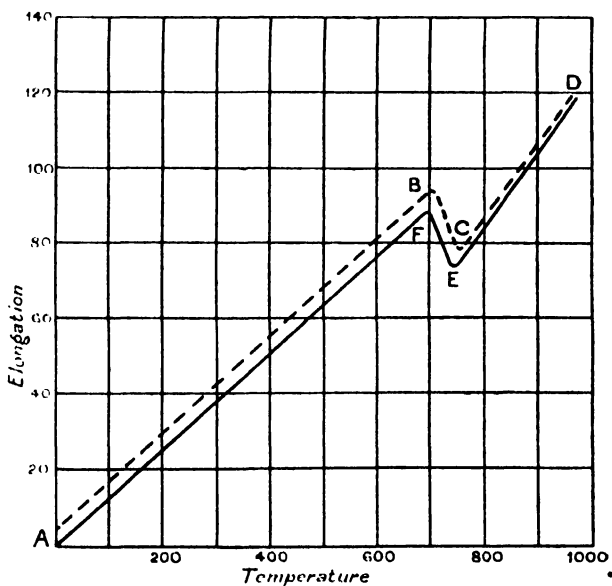


FIG. 8.—Group I. Steels. (Grenet).

either of the two following rates of cooling (1) 100°C. in 30 minutes, defined as slow cooling and (2) 100°C. in 10 minutes, defined as moderately slow cooling.

Adopting this method Grenet has proposed a classification of alloy steels into four groups.

Group I. These steels have approximately the same transformation temperature during cooling as on heating. (Fig. 8.) In this group are included the steels, the hysteresis effect of which on slow cooling is less than 150°C. In this category fall pure carbon steels and the majority of the alloy steels used commercially for structural purposes. None of these latter contain large amounts of alloying metal.

Group II. The steels in this group have approximately the same transformation temperature during slow cooling as on heating, but at moderate rates of cooling the transformation temperature on cooling is very much lower than of heating. (Figs. 9 and 10). The rate of cooling required to separate the two transformation temperatures also depends upon the maximum temperature reached and the length of time at this temperature. The best known examples in this group are furnished by high-speed tool steels (chromium-tungsten, chromium-molybdenum, chromium-tungsten-vanadium, chromium-tungsten-vanadium-cobalt). Provided these steels are not heated above a certain temperature they are approximately reversible. If that temperature is exceeded, however, the transformation point is suddenly lowered at ordinary rates of cooling and in this case there is, as a rule, a sudden drop of about 300°C. , viz., from 600° to 300°C. or below. No transformation takes place between these temperatures. If the conditions are suitably chosen, part

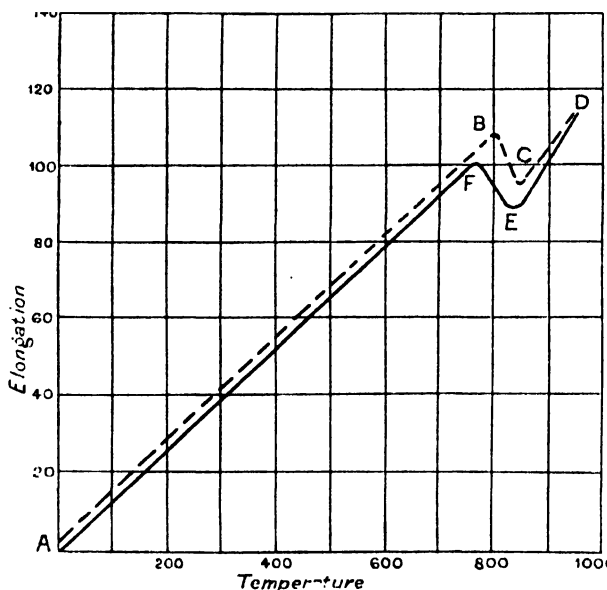


FIG. 9.—Group II. Steels. Very slow cooling. (Grenet).

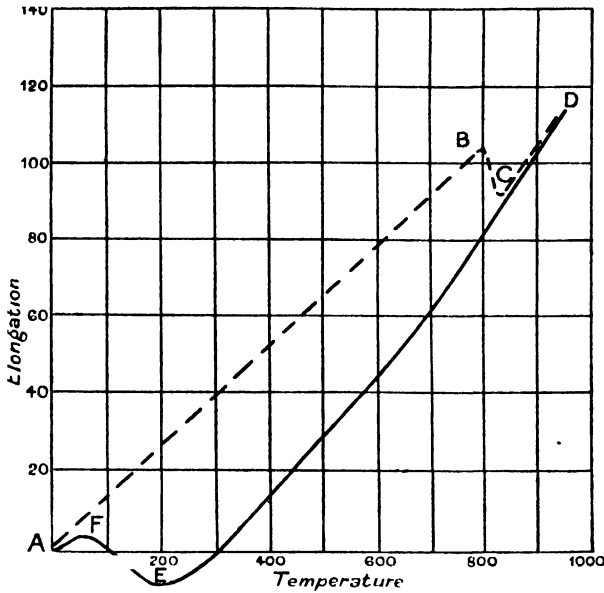


FIG. 10.—Group II. Steels. Medium rate of cooling. (Grenet).

of the transformation can be made to take place at above 600° and the remainder below 300°C. , the proportion depending upon the temperature and time.

► *Group III.* In this group fall all the steels whose transformation temperatures on cooling at very slow rates, differ from those on heating. (Fig. 11.)

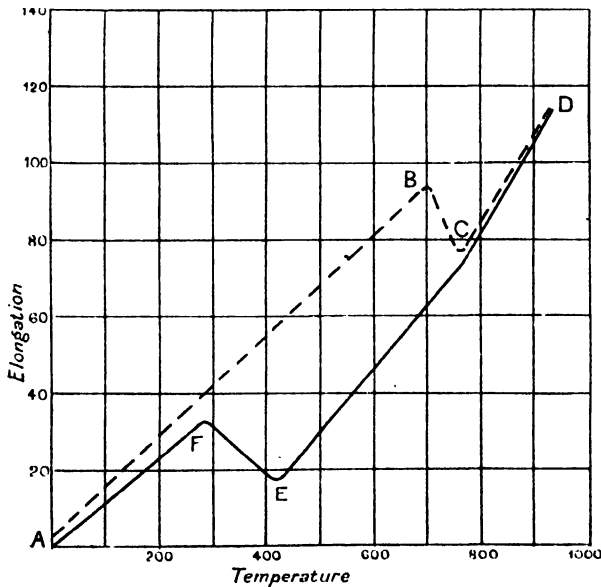


FIG. 11.—Group III. Steels. (Grenet).

Many nickel-chromium steels come within this category, e.g., all those containing from 3.5% to 6.0% of nickel with from 1% to 2% of chromium and less than 0.65% of carbon. When the chromium is partially or wholly replaced by manganese, tungsten or molybdenum, the steels still remain in this category. The transformation on cooling may occur at any temperature between the atmospheric temperature and the transformation temperature on heating. It is important to note, however, that the lowering of this point is not proportional to the quantity of the alloying element added, e.g., the addition of 1.7% of chromium to a 4% nickel steel lowers the transformation point on cooling from 600° to 200°C. Further additions of chromium, however, depress the transformation only very slightly. In the case of these steels, therefore, many of which are in common use, a slight variation in the chemical composition (1% of nickel plus 1% of chromium) suffices to depress the transformation on cooling about 400°C.

Since the transformation point is always lowered no matter how slow the rate of cooling, any heating of the steel above the transformation point on heating produces a quenching or hardening effect. To soften these steels, therefore, they must be subjected to a form of tempering by heating them *below* the transformation point on heating.

Group IV. The transformation temperatures of these steels on cooling are below the ordinary temperature. (Fig. 12). It will be seen that both heating and cooling curves are smooth and present no points of change. The principal examples of this class are furnished by steels of high nickel, high

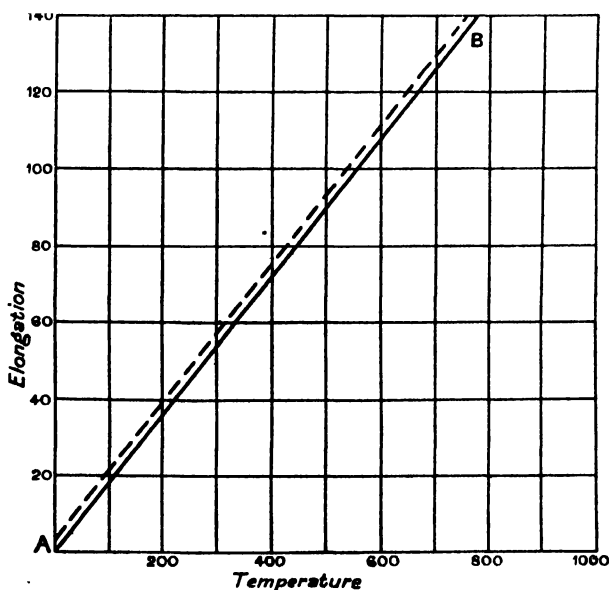


FIG. 12.—Group IV. Steels. (Grenet).

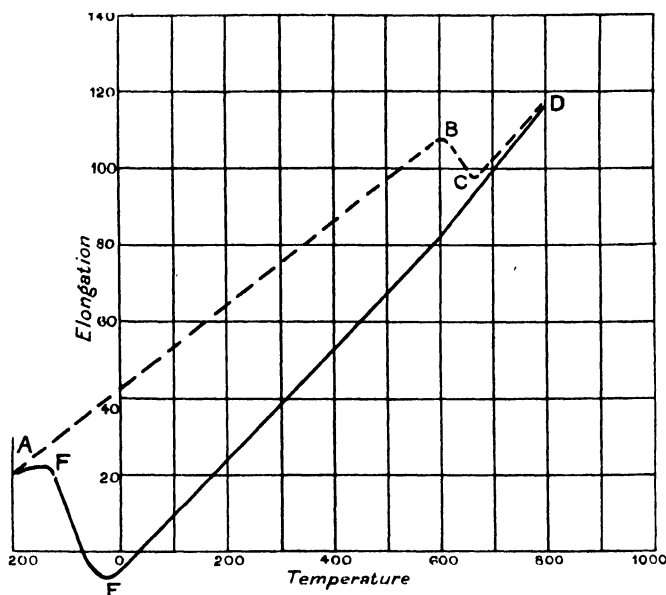


FIG. 13.—Group IV. Steels. (Grenet).

manganese, and high nickel-manganese content. In certain instances cooling below the atmospheric temperature produced the transformation as shown in Fig. 13. This group therefore furnishes the most pronounced example of hysteresis which may be as much as 700°C.

METHOD II.

The second method of classification is according to microscopic structure. Alloy steels can be classified according as they are (1) pearlitic, including sorbitic and troostitic, (2) martensitic, (3) austenitic or mixtures of these, or (4) contain double carbides. It is possible to construct diagrams in terms of these structures whose co-ordinates are percentages of carbon and the alloy elements concerned. These are not, however, equilibrium diagrams and it is necessary to emphasise this point. All that they do is to show the structure of any given alloy steel at the ordinary temperature, produced at the usual rates of cooling, as a function of the carbon and alloy metal contained. They may be called "structural" diagrams. They outline the areas occupied by various constituents whether "homogeneous" or "heterogeneous" and permit of a comparison of the various steels under similar conditions of cooling. By their use it is possible to form an estimate of the modifications in structure which may be produced in any given series of steels by altering either the carbon or alloy elements or both, and also some idea of the variation of mechanical properties which would then occur.

A word must be said as to the use of the constituents pearlite, sorbite, troostite, martensite and austenite. Strictly speaking these terms refer to the constituents formed on cooling pure carbon steels at different rates. As shown, however, in the case of the nickel steels, precisely the same sequence of structures may be produced not by varying the rate of cooling but by merely altering the composition. It is convenient, therefore, to use the same nomenclature, although strictly speaking the use of the terms should be qualified by adding the name of the alloying element in any given case, e.g., nickeliferous martensite, manganiferous austenite, etc. More especially is this important because the etching properties of alloy steel structures are not the same as those of pure carbon steel structures. Thus nickeliferous martensite etches less readily than martensite itself. Double carbides containing tungsten are less readily etched by sodium picrate the more tungsten they contain.

Reference is also necessary as to the structural form of the carbides which are characteristic of certain alloy steels, particularly those containing chromium, tungsten, molybdenum and vanadium. They usually appear on etched metal surfaces as small rounded grains, although they sometimes possess a geometrical form. Occasionally they are seen as films in relief after polishing. They are present in all unhardened high-speed cutting tools. They are not attacked by the usual etching reagents and therefore appear white in an otherwise etched specimen and show up very clearly. They are, however, attacked and coloured in some instances by sodium picrate. Certain double carbide steels, however, are very resistant, and can only be etched by such powerful reagents as molten potassium bisulphate and aqua regia. Even then the carbide constituent remains unattacked.

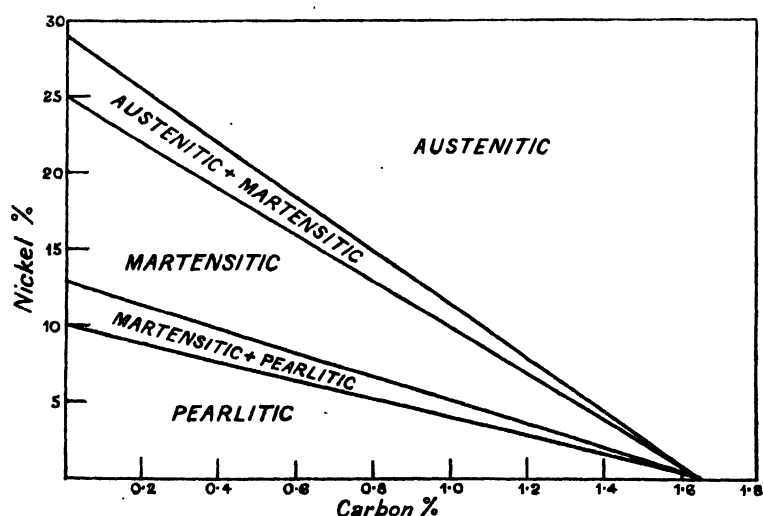


FIG. 14.—Nickel Steels. Structural Diagram. (Guillet).

Table VI shows the classification of alloy steels by structural diagrams, from which it will be seen that they can be grouped into types. Nickel and manganese fall into one class, while tungsten, molybdenum and vanadium come into the other. Chromium occupies an intermediate position and shares some of the characteristics of both types. Fig. 14 shows the structural diagram of nickel steels, from which it will be seen that five areas are present, (1) pearlitic steels, (2) pearlitic plus martensitic steels, (3) martensitic steels, (4) martensitic plus austenitic steels and (5) austenitic steels. By an inspection of this diagram it is possible to state what the structural composition of any nickel steel is corresponding to a given composition of nickel and carbon.

TABLE VI.
ALLOY STEELS. STRUCTURAL DIAGRAMS.
TWO TYPES.

Type.	
I.	Ni gives *Pearlitic, Martensitic and Austenitic Structures.
	Mn „ *Pearlitic, Martensitic and Austenitic Structures.
	Cr „ *Pearlitic (†Martensitic) and Double Carbide Structures.
	W „ *Pearlitic, and Double Carbide Structures.
II.	Mo „ *Pearlitic, and Double Carbide Structures.
	V „ *Pearlitic, and Double Carbide Structures.

The expression "double carbide structures" must be somewhat widely interpreted. Arnold and Read¹ have concluded that Chromium forms double and triple carbides made up of various proportions of Fe_3C , Cr_3C_2 , and Cr_4C . According to Arnold² Tungsten does not form a double carbide but a simple carbide W_2C . Tungstide of iron is liable to be formed, especially in high tungsten steels. Molybdenum³ forms a double carbide with iron $\text{Fe}_3\text{Mo}_2\text{C}$ or $\text{Fe}_4\text{Mo}_3\text{C}_2$. Vanadium⁴ forms a carbide V_4C_3 , but there is some doubt as to whether this unites with iron carbide forming a double carbide.

1. Journ., Iron and Steel Inst. 1911. No. 1.

2. Journ., Iron and Steel Inst. 1914. No. 1.

3. Journ., Iron and Steel Inst. 1916. No. 1.

4. Journ., Iron and Steel Inst. 1912. No. 1.

* Pearlitic includes Troostitic and Sorbitic.

† Disappears on slow cooling.

OBITUARY.

FREDERICK HENRY FAVIELL.—The Society has lost a very old Fellow by the death, on January 12th, at his residence at Walton-on-Thames, of Mr. Frederick Henry Faviell, who was elected a Life Member in 1887. He was born in India in 1852, and was the eldest son of the late F. Faviell, a well-known railway engineer, who assisted, in 1841, in the construction of the Eastern Counties Railway to Colchester. He superintended the construction of the viaduct at Lexden, Essex, and was afterwards engaged in many important railway undertakings in this country, and in India, Ceylon and South Africa.

NOTES ON BOOKS.

THE MIND. By various Authors. A series of Lectures delivered in King's College, London, during the Lent Term, 1927. Edited by R. J. S. McDowall. Introduction by Ernest Barker. London: Longmans, Green and Co. 8s. 6d. net.

This volume of short treatises on mental science by men of eminence, in which there is no germ of pre-arranged general view, and no trace of editorial supervision as regards doctrine, seems to establish a new and highly desirable status in works on mind. Hitherto the student has had but scant opportunity of finding all the leading views put forward with full and hearty advocacy in one and the same book; as every writer on a subject like mental science must tend towards unconsciously emphasising that with which he agrees and damping that which runs counter to his opinions.

Lecture I, "Biology," is by Professor Julian S. Huxley; the clear and unmistakeable keynote being, "Man is, from the physical point of view, but a single species: from the mental point of view he is a whole kingdom." The harmonic dominant is nervous interaction and the sub-dominant is evolution. On page eight we are introduced to a particularly unpleasant animal, the copperhead snake: the reader being presumed to be in a position to decapitate the reptile and to make an impressive experiment illustrating the general fact that the spinal cord is the organ which furnishes reflex outgoings. The freshly decapitated snake is to be laid out in a line and if not touched "it remains quiescent; but pinch the tail, and the headless animal will coil in its regular spiral and strike in the direction of the pinch." We are then led into a strain of thought which covers functional actions as bearing on mentality, the strain culminating on p. 48, where we have a lucid exposition of Lloyd Morgan's doctrine as to "prospective reference." The inner teaching of the lecture may be considered as being embodied in the one rather confident dictum:—"The material and the mental are inseparable" (p. 5).

Dr. McDowall, in the second lecture, which approaches the subject from physiology as a standpoint, appears to be mainly in agreement with the first lecturer, but there is more academic caution in the mode of expression; nevertheless Dr. McDowall commences with his conclusion. He says, on p. 53, "I begin, therefore, as a physiologist, with what I believe to be a fact, that the mind depends upon the brain."

A student who has carefully read both lectures may now have the book open at pp. 78 and 79; the former presenting to him the concluding words of Dr. McDowall's lecture, also the postscript, and the latter being the first page of Lecture III. The first two lectures appear confidently to postulate that mind does not and cannot possibly exist apart from matter; every concept of a separate creative or controlling mind being thus negated. If, however, the student proceeds to read the eight lectures which follow, even the first page of this renewed study will bring to his notice various views, which are contrary to those previously stated. The student may now fully realise that he has in his hands a work which is unique in its educational value; extremes in view and opinion, as also intermediates, being adequately considered.

The third lecture, in which Dr. E. A. P. Aveling discourses on psychology, commences with short references to the more notable views which have been put forward as to the nature of mind, and after this the lecturer sets himself to the task of dealing with the crude and dogmatic Cartesian, "*Cogito ergo sum*" in a cautious and scientific spirit; that is to say, educing from the "self" and its various knowings, believings and perceptions. Self is, he concludes, "a mental construct

which we produce by a process of synthesis." We are then led along paths of thought, sequence and reasoning; paths which each reader must leisurely travel by himself, until near the end of p. 94 we arrive at the absolute mind or *voûs* of Anaxagoras; this being the "Divine ordering principle in Nature." Dr. Aveling tells us that "in one guise or another" this concept has had the leading position "in the long history of thought." As a topical illustration of Aveling's dictum we may perhaps be allowed to touch on the question of recognition or denial of a separate ruling mind by the leading evolutionists.

Empedocles of Agrigentum (about 444 B.C.) is, we believe, the first who is known to have taught evolution in our Darwinian sense, and his *φρην ἱερή* corresponds to the *voûs* of Anaxagoras. Harris, in his "Philosophical Arrangements," edition of 1775, treats of evolution as taught by Empedocles and compares it with the evolutions of Lucretius and of Prior. He gives portions of the Greek text with various readings, also a portion rendered into English. We quote from Harris (p. 162), four lines from this rendering of Empedocles:—

" To him belong nor feet nor pliant knees ;
But mind alone he was ; ineffable,
And Holy Mind : that rapidly pervades
With providential care the mighty world."

Lucretius (Rome, about 60 B.C.), like Empedocles, wrote in verse, but he appears to be definitely materialistic; his subtle agencies as mind, sound and light being constituted by smaller atoms than ordinary matter. He mentions Empedocles and almost literally accepts the evolutionary parts.

Prior personifies the mind under the term Alma, and in his argument for the non-materialistic concept of the mind, he, like Dr. Aveling, strives to make Alma herself the judge.

Erasmus Darwin completed his final work, "Origin of Society" (Temple of Nature), about a year previously to his death in 1802, but the best edition, as printed with the additional notes, did not appear until 1825. Here the text and notes make the system of evolution full and consistent. The Divine ordering principle is fully recognised throughout the writings of Erasmus Darwin, for example, in Canto IV, l. 461, of "The Origin of Society," where this Supreme Mind is mentioned as one who:—

" With hand unseen directs the general cause."

Charles Darwin is as definite as his grandfather with respect to a Supreme Mind. On the concluding page (403) of the text, in the edition of "The Origin of Species" issued by Murray in 1902 there is mention of the "grandeur in this view of life"; the view being that of the volume as a whole, powers "having been originally breathed by the Creator into a few forms or into one." A similar sentiment as to the wonder of so setting a system that it operates from generation to generation is to be found on pp. 201-214 of the section on plants and animals in the Philosophical Essays of Isaac Watts, published in 1734.

Lecture V, "Physics," by Professor F. A. Lindemann, presents a concise view of wave atomics, as now explored by Shrödinger, C. G. Darwin and others; these aspects of study being allied to the energetic theory of matter put forward by Boscovich in 1759, and considered at length by Daubeney in the second or 1850 edition of his "Atomic Theory," published by the Oxford University Press. This rather easily accessible book by Daubeney gives a diagram on p. 37, which corresponds with the main equation of Boscovich and the sequences, pp. 34-50 and 465-470, include views by various eminent persons of the Victorian period; moreover, the recent studies of Haas on the cosmical formation of matter out of light quanta

("Nature," August 28th, 1926, also February 19th, 1927, p. 296) tend generally towards support of the views mentioned above. Dr. Lindemann strives for a framework of thought in which space and time are replaced by indefinables which allow more scope for dimensional speculations, and he presents the Bohr hydrogen atom as "an almost straight protonic line surrounded by a helical electronic thread."

The Rev. W. R. Matthews, in the sixth lecture, deals lucidly with the general aspects of "Philosophy," and on pp. 167-168 he tells us that mind makes nature: that is to say, if we accept the "principle of all idealistic theories."

Without attempting to deal, even briefly, with every lecture, we may say that the thorough and lucid manner in which widely differing views are considered should make the present volume a most generally useful contribution to the mental science of our time; but an index, cross-referencing, and a glossary of terms may be desirable additions to the new edition which will doubtless be required shortly.

MEETINGS OF THE SOCIETY.

ORDINARY MEETINGS.

Wednesday evenings at 8 o'clock (except where otherwise stated).

FEBRUARY 1.—CHARLES HERBERT WRIGHT, B.A., "Modern Aspects of Rubber Cultivation." SIR DAVID PRAIN, C.M.G., C.I.E., M.B., LL.D., F.R.S., will preside.

FEBRUARY 8.—HENRY D. WILKINSON, M.I.E.E., "Theatre Lighting." J. SWINBURNE, Esq., F.R.S., Member of the Council, will preside.

FEBRUARY 15.—CAPTAIN SIR ARTHUR CLARKE, K.B.E., Elder Brother of Trinity House and a Member of the Council of the Society, "Trinity House: its History and its Work."

FEBRUARY 22.—H. R. H. HALL, M.V.O., M.A., D.Litt., F.S.A., F.B.M., Keeper of the Department of Egyptian and Assyrian Antiquities, British Museum, "The Excavations at Ur from 1919-1926" (illustrated by lantern slides). LIEUT.-COL. SIR ARNOLD T. WILSON, K.C.I.E., C.S.I., C.M.G., D.S.O., will preside.

FEBRUARY 29.—ARCHIBALD CRAWFORD, K.C., Director of the Economic League, "Industry Fifty Years Hence." THE RT. HON. G. N. BARNES, P.C., C.H., Member of the Council of the Society, will preside.

MARCH 7 (at 8.30 p.m.).—J. H. JEANS, M.A., D.Sc., F.R.S., Secretary of the Royal Society, "Some Wider Problems of Cosmogony." (Trueman Wood Lecture.)

MARCH 14.—HAROLD G. BROWN, M.I.E.E., of the D.P. Battery Co., Ltd., "Lead Storage Batteries."

MARCH 28.—LIEUT.-COMMANDER R. T. GOULD, R.N., of the Hydrographic Department, Admiralty, "The Mechanism of the Modern Typewriter."

APRIL 18.—ALFRED C. BOSSOM, F.R.I.B.A., "American Architecture."

Dates to be hereafter announced:—

CAPTAIN ROBERT E. LLOYD-OWEN, M.C., A.M.I.E.E., "Loud-Speaker Characteristics."

CAPTAIN SIR BEACHCROFT TOWSE, V.C., K.C.V.O., C.B.E., "The Education of the Blind."

INDIAN SECTION.

Friday afternoons, at 4.30 o'clock.

FEBRUARY 10.—SIR EDWARD A. GAIT, K.C.S.I., C.I.E., "Ancient Bihar and Orissa." (Sir George Birdwood Memorial Lecture.) THE RT. HON. VISCOUNT CHELMSFORD, P.C., G.C.S.I., G.C.M.G., G.C.I.E., G.B.E., will preside.

MARCH 9.—LIEUT.-COLONEL I. A. E. EDWARDS, C.M.G., Deputy Director, Air Transport, Department of Civil Aviation, Air Ministry, "The Future Prospects of Civil Aviation in India." COLONEL THE MASTER OF SEMPILL will preside.

Date to be hereafter announced :—

SIR JAMES MACKENNA, C.I.E., "The Sugar Industry in India, Java and Mauritius."

DOMINIONS AND COLONIES SECTION.

Tuesday afternoons at 4.30 o'clock.

JANUARY 31.—THE RIGHT HON. LORD LOVAT, K.T., K.C.M.G., K.C.V.O., C.B., D.S.O., "Migration in the Empire." THE RIGHT HON. THE EARL OF CLARENDON, P.C., G.C.B., G.C.V.O., will preside.

FEBRUARY 28.—SIR STEPHEN MONTAGU BURROWS, C.I.E., "The Ancient Civilisation of Ceylon."

MAY 22.—CAPTAIN SIR CECIL ARMITAGE, K.B.E., C.M.G., D.S.O., "Gambia" (illustrated by lantern slides).

Date to be hereafter announced :—

COL. H. W. CROSTHWAITE, C.I.E., C.M.G., R.E., "Aerial Photography as applied to Survey."

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

ALBERT ERNEST DUNSTAN, D.Sc., F.I.C., F.C.S., "The Scientific Foundation of the Refining of Petroleum." Three lectures. January 16, 23 and 30.

H. GOUGH, M.B.E., B.Sc., "Fatigue Phenomena, with special reference to Single Crystals." Three Lectures. February 13, 20 and 27.

LECTURE I.—Definition. Early History. Problem of the existence of a fatigue range. Influence on the fatigue range of (a) Various types of applied stress systems, (b) Form and surface condition of metal, (c) Temperature, (d) Contact-substance (corrosion-fatigue). Typical fatigue fractures.

LECTURE II.—Fatigue under repeated impact. Cyclical stress. Strain relations and hysteresis effects. Fatigue phenomena of crystalline aggregates as exhibited by changes in micro-structure. Slip planes, slip directions, lattice structure. Use of stereographic projection in crystal problems.

LECTURE III.—Characteristics of deformation of metallic single crystals (zinc, aluminium, tungsten, brass, iron, etc.) under static forces. Fatigue of single crystals of aluminium and iron. Present position of theory of the fatigue of metals.

DR. MANN LECTURES.

A. G. HUNTLEY, May Construction Company, Ltd., "Applied Architectural Acoustics." Three lectures. April 16, 23 and 30.

LECTURE I.—History. Requirements of good Acoustics. Elementary theory. Echo. Reverberation. Absorption. Resonance. The Interference System.

LECTURE II.—Design. The Ripple Tank. Spark Method. The effect of different types of Ceilings. Materials. The application of theory to Design. Existing Buildings. Whispering Galleries.

LECTURE III.—A review of the Acoustic difficulties in certain buildings and how they have been overcome.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, JANUARY 30. Actuaries, Institute of, Staple Inn Hall, W.C. 5 p.m. Mr. J. Murray Lamb, "New National Life Tables (1921 Census)."
Farmers' Club, at the Whitehall Rooms, Hotel Metropole, S.W. 4 p.m. Mr. William Brunton, "Intensified Grazing."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Prince D. S. Mirsky, "The Russian Novel after 1880." (Lecture III.)

At University College, Gower Street, W.C. 2 p.m. Prof. Dr. R. W. Chambers, "The Northern Epic." 5 p.m. Dr. A. S. Parkes, "The Internal Secretions of the Gonads." (Lecture I.)

TUESDAY, JANUARY 31. Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. L. J. Hibbert, "Light, Colour and Colour Filters."

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Prof. A. P. Newton, "The Mercantile Empire, 1606-1783."

University of London, at Bedford College for Women, Regent's Park, N.W. 5.15 p.m. Prof. Dr. E. B. Poulton, "Recent Discoveries throwing new Light on some of the Commonest Insects."

At the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Sir Bernard Pares, "Russian History from Peter the Great to 1861." (Lecture II.)

At King's College, Strand, W.C. 5 p.m. Dr. J. A. Hewitt, "Integration in the Nervous System." (Lecture III.)

At University College, Gower Street, W.C. 5.30 p.m. Prof. Dr. P. Gevl, "Amsterdam in the 17th Century." (Lecture II.)

WEDNESDAY, FEBRUARY 1. Analysts, Society of Public, at Burlington House, W. 8 p.m. (1) Messrs. L. V. Cocks and E. Nightingale, "The Determination of Butter in Margarine." (2) Dr. B. S. Evans, "Deposition of Metals on Copper from Cyanide Solution: I.—A New Method for the Separation and Determination of small amounts of Lead." (3) Dr. W. R. Schoeller and Mr. A. R. Powell, "Investigation into the Analytical Chemistry of Tantalum, Niobium and their Mineral Associates: X.—The Separation of Silica from the Earth Acids. XI.—The Precipitation of Titanium by Tannin." (4) Prof. Dr. Joseph Reilly, "The Determination of Carvone in Dill Oil."

Archaeological Institute, Burlington House, W. 5 p.m. The Rev. Dr. A. C. Bouquet, "Turf-cut Images in the South of England."

Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Mr. C. H. B. Quennell, "House Building through the Centuries."

Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m.

Microscopical Society, 20, Hanover Square, W. Meeting of the Biological Section.

Oil and Colour Chemists' Association, at Painters' Hall, Little Trinity Lane, E.C. "The Painting of Cement and Plaster." (Joint Meeting with the Incorporated Institute of British Decorators.)

Public Health, Royal Institute of, 37, Russell Square, W.C. 4.30 p.m. Dr. Nathan Raw, "Medico-Legal Problems of Lunacy."

University of London, at King's College, Strand, W.C. 5.30 p.m. Mr. Henry Wickham Steed, "The Prelude to the War." (Lecture III.)

At University College, Gower Street, W.C. 3 p.m. Signor Camillo Pellizzi, "La Linea del Paradiso" (in Italian). (Lecture II.)

4 p.m. Professor A. V. Hill, "Muscle." (Lecture III.) 5.30 p.m. Mr. Charles Nowell, "The Provision of Commercial and Technical Literature in the Smaller Public Libraries."

5.30 p.m. Mr. J. H. Helweg, "Georg Brandes." (Lecture III.) 6 p.m. Prof. Dr. A. L. Bowley, "Measurement by

Index Numbers—Theory and Application to recent Economic History." (Lecture I.)

THURSDAY, FEBRUARY 2. Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m. Major H. N. Wylie, "The Design and Induction of Steel Aircraft."

Chemical Society, Burlington House, W. 8 p.m. Messrs. I. W. Jenkin and C. H. Desch, "Some Experiments on Diffusion in Solid Metals."

Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m.

Linnean Society, Burlington House, W. 5 p.m.

Mechanical Engineers, Institution of, at Manchester. Fifth Report of the Steam Nozzles Research Committee.

At Glasgow. Prof. C. J. Hawkes, "The Marine Oil-Engine." (Thomas Lowe Gray Lecture.)

Royal Society, Burlington House, W. 4.30 p.m.

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Sir William Bragg, "From Faraday's Note Books." (Lecture I.)

University of London, at Bedford College for Women, Regent's Park, N.W. 5.15 p.m. Sir Richard Terry, "What is Plainsong?"

At the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Lady Muir, "Bulgaria from the Liberation to the Balkan Wars, 1878-1912." (Lecture II.)

At King's College, Strand, W.C. 5.30 p.m. Mr. Ifor L. Evans, "Economic Aspects of Dualism in Austria-Hungary." (Lecture I.)

5.30 p.m. Dr. F. W. Rogers Brambell, "The Development of Sex, with special reference to recent work on Birds and Amphibians." (Lecture III.)

At the London School of Economics, Houghton Street, W.C. 5 p.m. Mr. H. J. Laski, "The Civil Service and Judicial Control."

At University College, Gower Street, W.C. 5 p.m. Dr. R. J. Ludford, "Cytology in Relation to Physiological Processes." (Lecture III.)

5.15 p.m. Prof. J. E. G. de Montmorency, "Customary Law in the British Empire." (Lecture II.)

5.30 p.m. Prof. Dr. Edmund G. Gardner, "The Carbonari."

Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Mr. M. J. Hanr, "Industrial Art in Czechoslovakia."

FRIDAY, FEBRUARY 3. Chemical Industry, Society of, Milton Hall, Deansgate, Manchester. 7.30 p.m. Messrs. S. A. Brazier and L. R. Ridgway, "The Influence of Zinc Oxide on the Coefficient of Vulcanisation."

Geologists' Association, at University College, Gower Street, W.C. 7 p.m. Mr. A. J. Bull, Presidential Address on "Further Aspects of the Mountain Building Problem."

Philological Society, at University College, Gower Street, W.C. 8 p.m.

Photographic Society, 35, Russell Square, W.C. 7 p.m. Meeting of the Pictorial Group.

Royal Institution, 21, Albemarle Street, W. 9 p.m. Prof. E. C. C. Balv, "Photo-synthesis."

Transport, Institute of, at Leeds. Mr. L. C. Harris, "Some Aspects of Shipping Transport."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Mr. Julian Krzyzanowski, "Polish Literature." (Lecture II.)

At King's College, Strand, W.C. 5.30 p.m. Dr. R. W. Seton-Watson, "The States of the Little Entente." (Lecture I.)

At University College, Gower Street, W.C. 5 p.m. Mr. C. F. A. Pantin, "Comparative Physiology." (Lecture IV.)

SATURDAY, FEBRUARY 4. L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Mrs. Robert Aitken, "Village Life in High Castle."

Royal Institution, 21, Albemarle Street, W. 3 p.m. Mr. H. C. Colles, "Musical London (1660-1759)." (Lecture I.)

JOURNAL OF THE ROYAL SOCIETY OF ARTS

No. 3924.

VOL. LXXVI.

FRIDAY, FEBRUARY 3rd, 1928.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK.

WEDNESDAY, FEBRUARY 8th, at 8 p.m. (Ordinary Meeting.) HENRY D. WILKINSON, M.I.E.E., "Theatre Lighting." J. SWINBURNE, Esq., F.R.S. Member of the Council, will preside.

FRIDAY, FEBRUARY 10th, at 4.30 p.m. (Sir George Birdwood Memorial Lecture.) SIR EDWARD A. GAIT, K.C.S.I., C.I.E., formerly Lieutenant-Governor of Bihar and Orissa, "Ancient Bihar and Orissa." THE RIGHT HON. VISCOUNT CHELMSFORD, P.C., G.C.S.I., G.C.M.G., G.C.I.E., G.B.E., will preside.

Tea will be served in the Library at 4 o'clock before the meeting.

COMPETITION OF INDUSTRIAL DESIGNS.

The Society's fifth annual Open Competition of Industrial Designs will be held in June next, when competitions will be held in the following sections:—Architectural Decoration, Textiles, Furniture, Book Production, Pottery and Glass, and Miscellaneous. Over £1,600 will be offered in prizes and scholarships in the various sections.

After the work has been judged a number of selected designs will be exhibited in London, and subsequently at suitable centres in the provinces. In this way they will be brought immediately to the notice of those manufacturers who are likely to be specially interested in them.

It is intended to confer the Society's Diploma on any candidate whose work reaches a very high standard of artistic ability and also shows practical knowledge of the materials and processes of his trade.

A Bureau of Information has been established at the Royal Society of Arts for the registration of the names and addresses of exhibitors who desire to obtain employment as designers. This Register is at the service of manufacturers in search of designers,

A summary of the prizes and scholarships was published in the *Journal* of January 6th, and full particulars can now be obtained on application to the Secretary of the Royal Society of Arts.

CANTOR LECTURES.

MONDAY, JANUARY 23rd, 1928. DR. ALBERT ERNEST DUNSTAN, D.Sc., F.I.C., F.C.S., delivered the second of his course of three lectures on "The Scientific Foundation of the Refining of Petroleum." The lectures will be published in the *Journal* during the summer recess.

NINTH ORDINARY MEETING.

WEDNESDAY, JANUARY 25th, 1928. DONALD WIPPELL, Esq., in the Chair.

A paper on "Enamels, Secular and Ecclesiastic," was read by MR. H. DE KONINGH. The paper and discussion will be published in the *Journal* dated March 9th.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

ALLOY STEELS THEIR MANUFACTURE, PROPERTIES, AND USES.

By H. C. H. CARPENTER, M.A., A.R.S.M., F.R.S.,

Professor of Metallurgy, Imperial College of Science and Technology.

LECTURE II.—TUNGSTEN STEELS. CHROMIUM STEELS. MANGANESE STEELS.

(Delivered November 21st, 1927.)

TUNGSTEN STEELS.

Mushet's air-hardened steel, which was the first of the alloy steels, is generally considered to be a simple tungsten steel. In addition to 6% of this metal, however, it also contained about 2% of manganese and 2% of carbon. The manganese was required to give the steel the self-hardening property. Actually, therefore, it was a quaternary steel. Special interest attaches to it in view of the fact that it was the pioneer among alloy steels. It had a remarkable career of usefulness and formed an indispensable link in the development of high-speed tools whose manufacture and properties will be discussed in the 4th Lecture. For some time it has been practically obsolete.

INFLUENCE OF TUNGSTEN ON THE MELTING POINTS AND INVERSIONS OF STEELS.

Iron melts at 1535°C. The addition of carbon lowers the melting point about 100°C. for every 1% addition of carbon. Tungsten melts at 3267°C. and as previously mentioned is the most refractory metal known. It is generally considered that it lowers the fusion point of steel. Mars (*) has given a table of the fusion points of tungsten steels ranging from 0.5% to 17% tungsten from which he has drawn his conclusion. If, however, his results are corrected for the lowering effects of the carbon, silicon and manganese present in the steels, some doubt arises as to whether this conclusion is correct. Thus a steel which contained 0.66% carbon, 0.03% silicon, 0.04% manganese and 3.11% tungsten fused at 1488°C. The carbon would lower the fusion point about 60°C., and the effect of the silicon and manganese would be inappreciable so that the plain iron tungsten alloy should fuse at about 1548°C., which is 13° above that of pure iron. This appears to be the effect of 3.11% of tungsten and it is not a lowering but a raising of the fusion point. Considering the refractoriness of tungsten, it may well be doubted whether it does really lower the fusion point of iron.

There is no doubt, however, that tungsten does lower the pearlite inversion in carbon steels when they are heated to a sufficiently high temperature. More than 20 years ago I showed that, (†) whereas the temperature of this change was about 700°C. in a steel containing 0.63% of carbon and 10.56% of tungsten when cooled from 1000°C. at a slow rate, it had dropped to about 550°C. when the same steel was cooled from 1200°C. Moreover, whereas the change completed itself within about 10° when the steel was cooled from 1000°, it was spread over about 100°C. when it was cooled from 1200°C. Interpreting these figures in the light of the work of Arnold and Read, quoted in the first lecture, it is clear that when the steel was not heated above 1000°C., iron carbide Fe_3C separated at the normal temperature of about 700°C. When it was heated to 1200°C., however, a mixture of iron carbide and tungsten carbide began to separate at 550°C. and continued to crystallise down to about 450°C. Tungsten carbide is not formed until the steel is heated to the neighbourhood of 1200°C. It then produces a lowering of the change point of from 150°C. to 250°C. Fig. 15 shows the structural diagram of the tungsten steels (‡).

MANUFACTURE OF TUNGSTEN STEEL.

Tungsten steel is nearly always made by crucible process. As mentioned in the first lecture, the world's production of alloy steel in 1925—7,217 tons—represents probably the tungsten steel manufacture of that year. Special care is required in charging the pots owing to the great difference between the

* Mars. G. Die Specialstähle Geschichte, Eigenschaften, Behandlung und Herstellung. Stuttgart, 1912.

† Journ. Iron and Steel Inst., 1905. No. 1.

‡ Metallography and Macrography. Guillet and Portevin, p. 182.

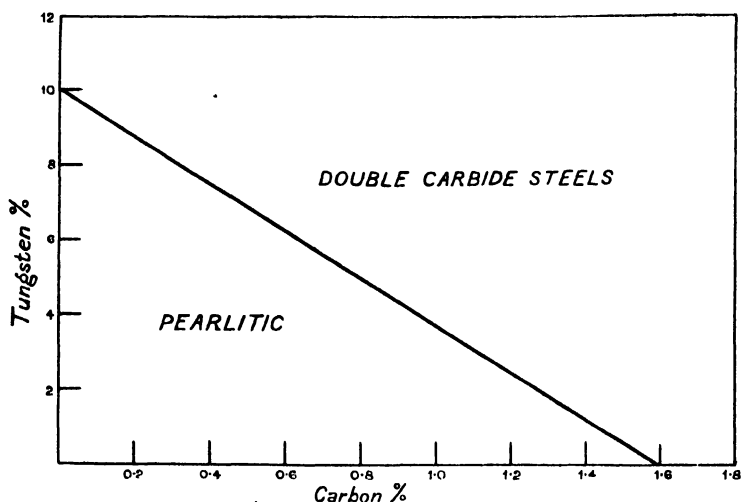


FIG. 15. Tungsten Steels. Structural Diagram (Guillet).

specific gravity of tungsten (19.3) and of steel (about 7.6). The tungsten is placed at the top of the charge and is gradually dissolved by the steel which melts long before it. If the tungsten were originally placed at the bottom of the crucible an infusible mush of rich tungsten alloy would form, which would neither pour out nor mix with the steel. Special care, therefore, is needed to get the tungsten melted and evenly dissolved. After melting, the steel is "killed" in the crucible by holding it in the furnace for at least 30 minutes. The contents may be cast either singly or doubly by hand-pouring or collectively by means of a ladle into which the contents of the pots are emptied. As a rule tungsten steel makes very sound solid ingots, though considerable piping takes place. It seems doubtful, owing to its low heat of combustion, whether tungsten aids in deoxidizing the steel. Its heat of combustion is about 1000 calories, whereas the burning of iron to Fe_2O_3 yields about 1600 calories. The heating, forging, and rolling of tungsten steels does not present any special problems or difficulties, and the processes adopted are similar to those employed with other high carbon steels.

PROPERTIES AND USES.

Plain tungsten steel is principally used in virtue of the magnetic qualities which it can be made to possess. It finds application in permanent magnets for electric meters, in small dynamos and for hand use. By far the greater part of the annual production consists of a steel containing about 6% of tungsten and from 0.6% to 0.75% of carbon. To obtain the best magnetic qualities it must be heat-treated and therefore all magnet steels are used in this condition. The process involves two operations, (1) the steels are hardened by

heating and quenching, (2) they are then magnetised, and if they are to be used for electric meters they are "seasoned" by a protracted heating at $100^{\circ}\text{C}.$ so as to make their magnetism as nearly constant as possible. I am indebted to Dr. W. H. Hatfield for the following data relative to the heat and magnetic treatment of these steels. They are quenched in water from $850^{\circ}\text{C}.$ and are used in this condition. The coercive force obtained depends largely upon the carbon content as is shown in the following table.

TABLE VII.

<i>Tungsten per cent.</i>	<i>Carbon per cent.</i>	<i>Coercive Force.</i>
6	0.60	58
6	0.65	63
6	0.70	68
6	0.75	72

Remanence is in all cases of the order of from 10,000 to 11,000. Two points are worth noting in connection with its heat treatment and alloying properties; (1) magnetic hardness is evidently associated with mechanical hardness, and (2) the quenching temperature is far below that at which tungsten carbide is formed, and therefore the special magnetic properties of the steels are evidently not caused by the formation of this carbide. The structure of the steel after quenching may be described as that of a fine "tungsten martensite" and the magnetic properties obtained are the properties of the structure. This structure holds for small magnets produced in this way. Large magnets are almost certain to contain in the interior some tungsten troostite.

The figures quoted for the coercive force are the best which can be expected from the composition given. It frequently happens, however, that they are not realised in practice owing to the conditions under which the steels have been prepared. When these are kept for any length of time at a high temperature such treatment has a deleterious effect upon the magnetic properties subsequently obtained. This effect occurs most rapidly at temperatures round about $950^{\circ}\text{C}.$ It also occurs fairly rapidly at $850^{\circ}\text{C}.$ itself, the hardening temperature, and the steel therefore must not be held too long at this temperature before being quenched. If the "spoiled" material be reheated to $1250^{\circ}\text{C}.$ and is then cooled in air, it is reconditioned and is then suitable for proper treatment. According to Evershed* the effect of heating to temperatures over $1100^{\circ}\text{C}.$ is to aid the retention of the gamma phase in the iron and to produce a reduced value of the remanence of the finished magnet. This difficulty may be removed by tempering at $700^{\circ}\text{C}.$ before the final quenching. Special care is needed in heating tungsten magnet steel owing to the readiness with which it decarburizes in an oxidising atmosphere.

* Journ. Inst. Elect. Eng., 63, p. 725. 1925.

MAGNET STEELS OF OTHER COMPOSITIONS.

A variety of other alloy steels have been proposed for magnet steels, viz., chromium-tungsten, chromium-cobalt, and cobalt-chromium steels. The following values have been furnished me by Dr. Hatfield as having been obtained with steels containing 1% of carbon and 1.4% chromium.

TABLE VIII.

<i>Treatment.</i>	<i>Coercive Force.</i>	<i>Remanence.</i>
Water quenching 860° C	65	9000
" " 820°	64.5	9850
" " 780°	61	10310

The addition of from 0.75% to 1% of chromium to a 6% tungsten steel appears to increase the coercive force slightly without seriously affecting the remanence. Evershed (loc. cit.) considers that the addition of chromium renders the material more liable to the effect of spoiling, but this matter does not yet appear to have been so thoroughly investigated as has been the case with tungsten steels. Cobalt magnet steel discovered by Honda and Takagi in 1917 contains essentially from 30% to 40% of cobalt with from 0.4% to 0.8% of carbon in the steel. In their patent specification, however, they extend the cobalt range to from 20% to 60%. They also give from 3% to 9% of tungsten and from 1.5% to 3% of chromium. The most suitable heat treatment for this steel is an oil quenching from 950° to 1000°C., when it is endowed with a coercive force of from 220 to 250, together with a remanence of the order of 10,000. On account of the high coercive force, however, magnetisation is difficult, and it is necessary to use very high magnetising fields, (1400 c.g. units) in order to obtain saturation and the high figures of remanence and coercive force quoted. Since the discovery of cobalt magnet steels, many patents of steels containing varying amounts of cobalt with additions of other elements have been taken out. Among them may be mentioned those of Hadfield in this country, Krupp in Germany, and Sumitomo Chukosho in Japan. These cover a very wide range of composition and properties. According to Kayser (†), steels of the composition chromium 9% to 15%, cobalt 1% to 18%, and carbon above 1% are air hardening. He also states that cobalt, within fairly wide limits, increases the coercive force according to the relation $H_c = h (1 + k Co)$ where h = the coercive force of the cobalt-free base and k is a constant which depends on the base alloy and which, for properly hardened samples, reaches a maximum with chromium from 9% to 14%, and carbon 1%. It must be confessed that we are completely ignorant of how these alloying metals act in improving the magnetic qualities of the carbon steels. The compositions

† Engineer, Jan. 19th, 1923, p. 57.

quoted have been arrived at empirically by experiment. The explanation of their action must await proper scientific investigation.

CHROMIUM STEELS.

Plain chromium steels were some of the earliest alloy steels to be made. They were used for a variety of purposes, in all of which, however, the property of hardness was an important factor. These uses date from about the year 1880. It is very remarkable that an entirely new use for chromium steels was discovered more than 30 years later, particularly as the literature of the last 20 years of the 19th century and the first 12 years of the 20th century contains many references to the preparation and properties of chromium steels. Mention may be made of the extensive researches of Sir Robert Hadfield in this country and Messrs. Guillet and Portevin in France, into the properties of chromium steels, but neither of these investigators nor any others up to 1923 discovered that high chromium steels, when suitably heat treated, were remarkably resistant to corrosion. This particular discovery was made by Mr. H. Brearley in 1913 and was, as is often the case, a chance discovery. It has resulted in the production and manufacture of the numerous varieties of "stainless" steels which are now on the market. So rapid and important have been the manufacturing developments that have followed on Mr. Brearley's discovery that the corrosion and staining-resisting properties of heat-treated chromium steels now constitute the most important application of this alloy metal.

INFLUENCE OF CHROMIUM ON THE MELTING POINTS AND INVERSIONS OF STEEL.

The melting points of iron and chromium are almost the same. That of iron is 1535° and that of chromium is 1525°C . Chromium accordingly has very little effect on the melting point of iron. The two metals mix readily in the liquid state and they have the same crystal lattice (a body-centred cube). There is little doubt that these are favourable factors in producing the valuable properties which chromium steels possess.

In contrast to tungsten, chromium does not lower the pearlite inversion in carbon steels but actually raises it. This is seen in the following table which gives the temperature of the A_{r1} change in chromium steels of ascending chromium content. All the steels are cooled from 900°C .

TABLE IX.

<i>Percentage of Chromium.</i>	<i>Constituent.</i>	<i>Temperature of A_{r1} Inversion. ° C.</i>
zero	Pure Pearlite.	715°
1.10	Chromiferous Pearlite.	729°
3.24	" "	758°
9.55	" "	776°

The figures show that the temperature of the pearlite inversion (change to carbide carbon) is raised from 715° in pure pearlite to 776°C. in a chromiferous pearlite containing 9.55% of carbon. This is evidently due to the gradual formation of the carbide Cr_3C_2 and the formation of a double carbide or carbides with Fe_3C . Chromium therefore is quite different from most of the other alloying metals in that it does not lower the temperature of the Ar_1 change. Indeed it hastens it, since the inversion takes place at a higher temperature, the actual amount of which depends on the percentage of chromium in the steel. There is also a further difference from tungsten in that the temperature of the Ar_1 inversion is almost independent of the temperature from which the steel is cooled. Many years ago I showed ($\dagger$) that the lowering produced by cooling from 1250°C. as compared with the temperature of the inversion obtained by cooling from 900°C. was not more than 25°C. These two properties differentiate chromium from tungsten, and, it may be added, from molybdenum, manganese and nickel. Very high percentages of chromium, however, e.g., steels containing upwards of 30% of this alloy metal, do show a tendency to hysteresis, and martensitic structures are obtained unless the rate of cooling is very slow. Given sufficient time, however, the martensitic structure disappears on annealing and is replaced by a carbide structure. The structural Diagram of the Chromium Steels is shown in Fig. 16.

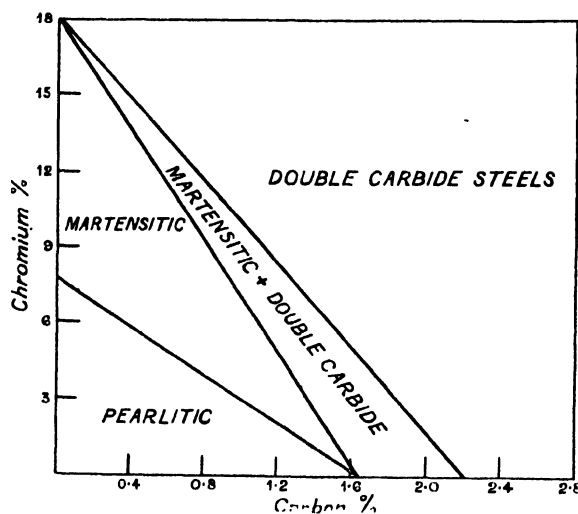


FIG. 16. Chromium Steels. Structural Diagram (Guillet).

MANUFACTURE OF CHROMIUM STEELS.

The production of plain chromium steel ingots in 1913 was probably about 6,000 tons, with a content of chromium of from 0.4% to 2%. They were made either by the acid open-hearth or the crucible process. Stainless steels

$\dagger$ Journ. Iron and Steel Inst., 1905, No. 1, Plates 40 and 41.

which contain considerably more chromium, viz., from 12% to 20% or even higher, are generally manufactured in the electric furnace. When made in crucibles the chromium, added in the form of ferro-chromium, was a part of the original charge. When manufactured in the open-hearth furnace, however, the ferro-chromium was added just long enough before casting for the alloy to be melted and well mixed with the charge. Mr. Hibbard (*) estimates that the consumption of ferro-chromium for steel making in the U.S.A. in 1913 was between 3,000 and 4,000 tons, containing from 60% to 70% of chromium. Assuming an average content of chromium of 1% in the structural steels and 4% in the high-speed tool steels, he estimated a total production of 204,000 tons of steel of all kinds containing chromium. It is quite certain that at the present time the output is considerably larger in view of the great development of stainless steels for a variety of uses.

At steel-melting temperatures chromium has a greater affinity for oxygen than has iron. If, therefore, oxygen either free or in the form of oxide of iron, comes in contact with melted steel containing chromium, some of the chromium is wasted by oxidation. This is the reason why in the manufacture of steel in the open-hearth furnace the ferro-chromium is added at the latest possible stage of the melting. Chromium steels can be cast, forged and worked by the same plant, and the same methods, as carbon steels of the same or slightly higher carbon content. The effect of adding chromium up to a maximum of about 2½% in steel is to increase the hardness moderately when the steel is in the unhardened state. The hardening effect is much greater, however, when the steel is quenched, and practically all chromium steels are used in the heat-treated condition in order to get the full value of the presence of this element.

PROPERTIES AND USES.

The oldest use of chromium steels which is still current, is for stamp shoes and dies for crushing gold and silver ores. These contain from 0.8% to 0.9% of carbon, with 0.4% to 0.5% of chromium. Toughness as well as hardness are essential properties of these steels, and some annealing is always employed in their heat treatment. This increases their durability to a marked extent. Another important use is in the form of 5-ply plates for the manufacture of safes. These safes are made of five alternate layers, two of chromium steel and three of soft steel or wrought iron. The thickness of the plates is usually between ½" and 1" so that a safe wall or door, if required to be more than 1" thick, must be formed of two or more thicknesses screwed together. Hardened chromium steel rolls containing 2% of chromium and 0.9% of carbon are used for cold-rolling metals. These are glass hard. Another important use is in the manufacture of files. Nearly half the total manufacture of 1913 in the U.S.A. went into the production of files containing carbon from 1.3% to 1.5% and chromium about 0.5%. Balls and rollers for bearings are generally made of

* Loc. cit., p. 19.

chromium steels. The composition frequently used is carbon 1.1%, chromium 1.4%, manganese 0.35% and sulphur and phosphorus each not exceeding 0.025%. All sizes smaller than 0.5 inch diameter are water-quenched from about 770°C. and then tempered at 190°C. for 30 minutes. Larger balls are quenched from about 800°C. The temperature of the second heating is too low to produce any temper colours, but is sufficient to remove to some extent the internal stresses set up in quenching. By this means, therefore, the balls are toughened and rendered less liable to crack. Mr. Hibbard states "The strength of a good well-treated ball is prodigious. A ball $\frac{3}{4}$ " diameter tested by the $\frac{3}{4}$ -ball method sustained a load of 52,000 lbs. On the small area of contact the intensity of the pressure amounted to over one million lbs. per square inch." At one time chromium steels were used in armour-piercing projectiles. These, however, have been almost entirely displaced by nickel-chromium steels (see Lecture III). It will be observed that in all these uses the quality of hardness was the outstanding property. Inasmuch as the steels are used in the quenched condition the hardness may be attributed to the properties of chromiferous martensite and possibly to the existence of hard carbides.

As previously mentioned, Mr. Brearley's discovery of the corrosion-resisting properties of chromium steels was unpremeditated (†). He was engaged at the time in a research on the resistance to erosion of various steels for ordnance purposes. Among the steels examined were some containing large amounts of chromium in different conditions of heat treatment. It was noticed that the high chromium steels were either not etched at all or could only be slightly etched by the usual agents employed in the microscopic examination of steel sections, and further, that they did not rust in the atmosphere of the physical laboratory. Under certain conditions produced by heat treatment, however, these steels could be etched and did not exhibit anti-rusting properties to any thing like the same degree.

Mr. Brearley's patent, the terms of which are published in Mr. Monypenny's book, states, "A typical composition for the untarnishable steel embodied in my invention would be as follows:—carbon 0.24%, manganese 0.30%, chromium 13.0%, iron 86.46%. In producing such steel embodying my invention I preferably use an electric arc-melting furnace. It can be readily made in such a furnace. It forges easily into sheets or strips such as are required for knife blades for example, and can be hardened and tempered by ordinary commercial processes. It is suitable also for structural purposes, the following being the average mechanical properties after small bars of steel of the above composition have been oil-hardened at 900°C. and tempered at 700°C., e.g.:

Yield point	...	...	...	39 tons per square inch.
Maximum stress	...	...	...	48 tons per square inch.

† A full account of this will be found in Mr. Monypenny's "Stainless Iron and Steel," Chapman and Hall, Ltd. 1926.

Elongation	...	...	...	25% on 2" x 0.564" test piece.
Reduction of area	...	...	...	63%.
Izod impact figure	...	...	...	86 foot lbs."

It is made clear in the patent specification that if this steel is to be resistant to corrosion, it must not contain any microscopically distinguishable free carbides. The corrosion-resisting properties of this steel, therefore, which is a low carbon high chromium steel, are dependent upon the whole of the carbon being dissolved. Here again, therefore, the structure is essentially that of a chromiferous martensite. The hardening temperature of this steel, it is to be noted, is about 100°C. higher than that of a pure carbon steel and extends over a wider range. This is due to the raising of the A_{c1} point by the large amount of chromium present.

This discovery of Mr. Brearley's has proved very fruitful and has led to the manufacture of steels of a new type, viz., the stainless steels. Not all of these are plain chromium steels—some of them contain nickel as well—but all of them without exception contain chromium in considerable amounts, and the essential corrosion-resisting properties are due to this metal.

Stainless steel was introduced to the public in 1914 in the form of table cutlery and as Mr. Monypenny points out (page 6): "The fact that it was almost exclusively used for cutlery purposes for a considerable period of time after that date, has led to the belief, probably widely held, that stainless steel is simply a special type of cutlery steel with a very limited range of mechanical properties. It has even been considered to be a special form of plating. If this were so, stainless material would have a very limited application and would not be of great interest to engineers. Fortunately, however, this is not the case. Stainless steel is really a whole series of steels whose mechanical and physical properties vary widely in a similar manner to the variations met with in the different varieties or tempers of ordinary carbon steels, but which all have the distinguishing property of great resistance to corrosion conferred on them primarily by the presence of a considerable percentage of chromium. As a general rule the amount of this element present in stainless materials is in the range of from 7% to 14%."

Very little opportunity occurred for developing stainless steel for engineering purposes until after the end of the war. Since 1919, however, considerable progress in the use of these steels has been made in several directions, while their possibilities have been indicated in other directions. From its initial use for table cutlery has come, in natural sequence, its development for all classes of knives, scissors and surgical instruments. A softer material is required for the manufacture of forks and spoons and both stainless iron, i.e., a chromium iron alloy very low in carbon and certain chromium nickel alloys have found application. Some use has been made of stainless steel for the manufacture of valves for aeroplane engines. In this case strength at high temperatures and resistance to corrosion and oxidation while hot are the prime desiderata.

A rather higher carbon and somewhat lower chromium content has been found suitable for such steels. Another engineering development has been in connection with hydraulic and steam service work. For the past two or three years several locomotives have been in continuous service fitted with stainless steel valves of various kinds, blow-off cocks, water gauge fittings, injector cones, valves, piston rods, valve rods, and brake rods. In the case of safety valves the stainless steel seating is simply pressed into the cast iron or cast steel valve body. Another application has been to turbine blading where the conditions are different from any hitherto described. In the case of turbines of the impulse type it is necessary to use soft and not springy steel so that it may be easily pressed into shape, and when so pressed will take accurately the shape needed. For this purpose a mild stainless steel or stainless iron containing from 0.10% to 0.15% of carbon has been used. The foregoing are a few of the applications to engineering of stainless steels and irons. It seems likely that there will be considerable developments in the future use of such materials if the experience gained in these earlier tests is satisfactory.

As previously mentioned, stainless steel requires a special heat treatment in order to develop its corrosion-resisting properties. Taking as an example the most widely used variety, viz., cutlery steel containing about 0.24% of carbon and 13% of chromium, in order to get the maximum resistance the whole of the carbon must be dissolved in the steel. Unless this is the case, and to the extent to which it is not the case, resistance to staining and corrosion is diminished. The reason for this is as follows:—If the steel is allowed to cool slowly and carbon segregates at the A_{r1} point as carbide, by far the greater part of the chromium segregates with it and a comparatively small amount remains dissolved in the iron. In such a mixture the chromiferous iron will offer less resistance to corrosion than the carbide segregate and corrosion will accordingly take place in this constituent. It is necessary to employ quenching either in water or oil, or, in the case of a very thin article, air cooling, not merely to preserve the carbon but also the chromium uniformly distributed in solid solution in the iron. It is this solution which exhibits the maximum resistance to tarnishing, staining and corrosion.

The stability of iron chromium alloys under corroding influences has been shown to be due to passivity. The work of Tammann and Sotter¹ and still more recently of Strauss² has shown this clearly. Strauss has found that alloys containing only small amounts of chromium assume a negative potential (about - 0.6 volts) in normal ferrous sulphate, while those containing large amounts of chromium assume a "noble" potential (about + 0.2 volts). There is a sudden jump from the negative (active) potential to the positive (passive) value, but the percentage of chromium at which the jump occurs depends on a number of factors, e.g., the carbon content, the state of the metal (whether

1. G. Tammann and E. Sotter. *Zeitsch. Anorg. Chem.* 127. (1923), 257.

2. B. Strauss. *Stahl. u. Eisen.* 45. (1925) 1198.

cast or forged), and the steps taken to exclude oxygen. Recent work by Benedicks and Sundberg³ shows that the "noble" potential of stainless steel is due to oxygen. If measured in hydrogen the value is similar to that of ordinary iron. The passivity is therefore due to an oxide film just as in the case of iron itself, as has recently been shown by U. R. Evans.⁴ The chromium content required to produce passivity increases with the carbon content in the steel.

As U. R. Evans has recently pointed out⁵, "it is significant that the resistance of ordinary stainless steel towards dilute sulphuric acid is greatly increased if the material has received a preliminary treatment in nitric acid or other oxidizing agent." This confirms the view that immunity is due to a high protective oxide film. This film, however, is probably not thicker but thinner than that present on ordinary metals because the protective character will hinder its own growth. In so far as corrosion does occur it is often to be found at places where there is least oxygen, e.g., at narrow crannies where two pieces come almost but not quite, into contact.

Recent progress in the manufacture of corrosion-resisting alloys has depended on the use of nickel in addition to chromium. The alloy manufactured in England under the name of "Staybrite" contains 18% of chromium and from 8% to 9% of nickel. The German alloy known as V2A contains from 20% to 25% of chromium and 6% of nickel. Unlike ordinary stainless steel, which is a two-phase alloy in the unhardened state, these alloys consist of a single phase. The iron is in the gamma (austenite) condition. These alloys are ductile and can be worked into almost any form. "Staybrite" can also be welded. Unlike, however, the stainless steels containing only chromium as an alloying element, it cannot be hardened by quenching, although a certain amount of work-hardening can be obtained. These alloys resist various acids which appreciably attack ordinary stainless steels, notably phosphoric, acetic, formic, tartaric and citric acids. When completely immersed in sea-water at the ordinary temperature "Staybrite" appears incorrodible. Partial immersion, however, especially in aerated sea-water, may cause a breakdown at the water level and the attack spreads from that point along the entire water line.

MANGANESE STEELS.

The metal manganese occupies a position of peculiar importance in steel metallurgy. It is required in the manufacture of all ordinary steels and in spite of a large amount of investigation no satisfactory substitute has yet been found for it. Very large quantities are therefore annually used for this purpose. It is also a constituent for one of the most important alloys ever made—the so-called "Manganese steel." This alloy in the commercial meaning of the name, is a variety of steel containing from 1.0% to 1.3% of carbon and from

3. Journ. Iron and Stee. Inst., 114. 1926.

4. Journ. Chemical Society, 1927.

5. Corrosion of Metals, 1926, p. 231.

11% to 14% of manganese. The original patents covered steels with from 7% to 30% of this metal, but alloys within the limits of the composition given have the greatest strength and ductility and are, therefore, generally used. The discovery of this steel and the working out of its properties over a period of many years will always be associated with the name of Sir Robert Hadfield. It undoubtedly is one of the most important alloy steels ever discovered and certainly it has become the most famous of any. It was the pioneer of steels of a new type and the economies resulting from its use in various fields of service have been remarkable. As Mr. Hibbard¹ has pointed out: "Perhaps the most conspicuous example of its use was in connection with the Panama Canal where years of time and millions of expense were saved by its use." The bulk of the manganese steel made at the present time is employed in the form of castings, but the use of hot-worked (rolled and/or forged) manganese steel is now also of considerable importance.

THE INFLUENCE OF MANGANESE ON THE MELTING POINTS AND INVERSIONS OF CARBON STEELS.

Manganese is by far the most fusible of the metals used in Alloy Steel Metallurgy. Its melting point is about 1260°C. Its addition to iron lowers the melting point fairly uniformly from 1535°C., and the melting ranges of all alloys lie on a smooth curve between these two points. Manganese steel of the above composition melts at about 1325°C., whereas a pure carbon steel of the same carbon percentage melts at about 100° higher. This increase in fusibility is commercially advantageous because it lowers the cost of founding the steel.

Manganese also lowers the inversion points of steels. Its action indeed is similar to that of nickel whose influence has been described in Lecture I, but it is more powerful. Broadly speaking, the amount of manganese required to produce a definite lowering in the change point of a steel is only half what would be required in the case of nickel. Rather less than 14% is needed, e.g., to preserve iron in the gamma condition at the ordinary temperature whereas 29% of nickel is required for the same purpose. The transformation to martensite can be produced with 6% of manganese as compared with 13% of nickel. The structural diagrams of the two series of alloys are accordingly very similar. That of manganese is given in Fig. 17. From this it will be seen that manganese steel is an austenitic steel well within the austenite area. Its remarkable properties are undoubtedly connected with this characteristic structure.

MANUFACTURE.

Manganese steel is still made in the ladle, according to Hadfield's expired patents, by mixing decarburized iron containing not more than 0.1% of carbon with 80% ferro-manganese. The iron is melted either in a pneumatic converter

1. Loc. cit., p. 39.

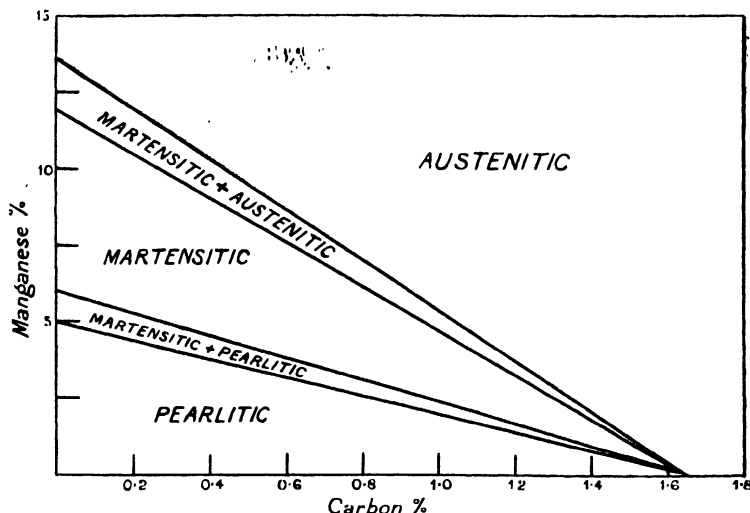


FIG. 17. Manganese Steels. Structural Diagram (Guillet).

or an open-hearth furnace. The ferro-manganese has also to be melted or at any rate heated nearly to the melting point, since it forms such a large proportion of the charge, viz., about one-seventh. This process is usually effected in graphite crucibles heated in coal-fired melting holes. The life of these pots is from 8 to 10 heats. Allowance has to be made for loss of manganese by oxidation. If a finished steel is required to contain 12.5% then about 14% of manganese must be used in the charge. Efforts have been made to melt the ferro-manganese in a cupola because of the high cost of melting in pots. In this case, however, there is always more loss of manganese which off-sets to some extent the lower cost of melting. The loss can be diminished by charging the ferro-manganese in the centre of the cupola and surrounding it with coke so that the metal is largely protected from the free oxygen of the blast.

The steel is usually made and handled in clay-lined ladles. Such a lining is, of course, acid, and is sometimes strongly so, particularly when quartz in the form of sand or ganister is mixed with the clay. The principal slag formed is a silicate of manganese, green in colour. It is thin and fluid and special care is required to prevent it from entering the moulds when the steel is cast. A "coffee-pot" ladle is sometimes used provided with a spout like that of a coffee-pot attached on one side and connecting with the ladle interior at the bottom. With this arrangement the slag cannot enter the spout until nearly all the steel has been poured from the ladle. The steel is very fluid in the liquid condition, and this property favours the running of intricate castings. When properly made the casts are usually free from gas holes. Where, however, the decarburized iron has been heated to too high a temperature before mixing with the ferro-manganese, it contains too high a gas content and the castings are liable to contain many blow-holes.

COMPOSITION AND PROPERTIES.

Analyses of manganese steel lie between the following limits :—carbon from 1.0% to 1.3%, manganese 11.0% to 14.0%, silicon 0.3% to 0.8%, phosphorus 0.05% to 0.08%. The sulphur content is so low as to be negligible. Steels containing from 7-8% of manganese, however, are finding some use. They have a higher and better defined elastic limit than the steel whose analysis has just been quoted. Their ductility, however, is very much less, but they are cheaper to make, and they do not flow under impact so freely as the ordinary, commercial grades. Their structure is martensitic and not austenitic.

Manganese steel may be regarded as a hard self-hardening steel owing this property to its composition. It cannot be softened by heating followed by slow cooling but requires an accelerated rate of cooling. It has a high coefficient of expansion and small patterns are made with a shrinkage of five-sixteenths of an inch to one foot, which sometimes is not quite enough. Its specific gravity is about the same as that of a plain carbon steel of the same carbon content. For a metal it is a poor conductor of electricity. Perhaps its most remarkable property is its almost total lack of magnetic permeability and susceptibility. Although it contains 85% of iron in a metallic form, it is so slightly attracted by a magnet that no pull can be felt with the hand. As contrasted with this, magnetic oxide of iron containing about 70% of iron in a non-magnetic form is quite strongly attracted.

In the untreated state the properties of manganese steel are similar to those of untreated high carbon steels. The metal is very hard and its ductility is almost negligible. In order to develop the toughness, which is so characteristic a property, special treatment is required. This method was discovered by Hadfield and is set forth in his early papers on the subject.¹ It consists in heating the article in question to 1050°C. and then quenching it as rapidly as possible in cold water. Special care is needed to ensure that this operation is successful. The steel is a poor conductor of heat, a fact which does not make its heat treatment easy, and tends to limit the thickness of the steel that may be profitably treated, which is generally taken as about 4 inches. It also requires to be heated slowly. This must not be done by placing the cold metal in a hot furnace. If this is attempted the temperature of the skin rises too rapidly and heat cannot pass to the interior. The high coefficient of expansion of the metal causes an expansion which is sufficient to crack and tear the metal. For successful heat treatment both the specimen and the furnace must be heated simultaneously from the same initial temperature. Care is required to avoid scaling of this oxidizable alloy, otherwise it will not quench properly.

1. Hadfield. On Manganese Steel, Journ. Iron and Steel Inst., 1888, pt. 2, pp. 41-82. Manganese and its Application to Metallurgy, Proc. Inst. Civ. Eng., Vol. 93, pt. 3, 1887-88, pp. 1-16. Some Newly Discovered Properties of Iron and Manganese loc. cit., pp. 61-126.

PROPERTIES OF HEAT-TREATED MANGANESE STEEL.

Hadfield's papers just referred to give the results of a large number of tests of heat-treated manganese steels. These showed that the toughening effected by water quenching was produced only when the steel contained at least 9% of manganese. The hardness of toughened steel is unique in that it was the first example obtained of an alloy steel which is both hard and tough. Hardness is tested by a variety of methods each of which tests a particular aspect of this composite property. From these somewhat varying conclusions can be drawn as to the hardness of manganese steel. It can be easily dented with a hammer and marked with a file or a chisel. Its Brinell ball hardness is not high. Its elastic limit is surprisingly low. None of the results would suggest it was a particularly hard alloy. It cannot, however, be cut and its machining by cutting tools is almost if not quite impracticable. It has to be ground to shape with an abrasive wheel. The water toughening described gives it great ductility, particularly in respect of elongation, which is greater than that of almost any other steel, and sometimes exceeds 50% on 8 inches. In spite of this its high degree of hardness is not greatly altered. Practically all manganese steel is used in the toughened state, and the combination of hardness with ductility thus achieved gives great resistance to abrasive wear as well as safety from breakage.

A tensile test of this steel gives a quite unusual result, the percentage contraction of area being less than the percentage elongation. In the case of most steels, both carbon and alloy, the percentage of contraction is usually about twice that of the elongation. Accordingly in this case the elongated test piece has a uniform stretch throughout its length and a comparatively slight reduction at fracture, whereas most steels have a largely increased amount of stretch near the point of fracture. Hibbard¹ states: "When a piece of manganese steel is pulled the increase of strength due to cold working (stretching) is greater than the decrease in the cross section due to contraction, so that a stretched part becomes stronger than the unstretched parts and elongation then occurs at another place. As the pulling is continued all parts of the pulled sections stretch one after the other with the result that when the piece is finally ruptured, the stretch has been comparatively uniform. There is indeed an increased local extension and contraction close to the point of rupture, as with other ductile steels, but is it less marked in the manganese steels."

Another surprising property of this steel is its elastic limit. It is unusually low and ill-defined. Indeed it is doubtful whether it can be said to have, strictly speaking, an elastic limit at all. The stress strain diagram shows no marked break in the curve and it is very difficult to decide where the elastic limit begins. The tensile test of a heat-treated manganese steel from a test bar cast 3 inches square and forged to a testpiece 0.823 inches in diameter gave the following results :—

1. Loc. cit. page 31.

Gauge length	...	...	...	2 inches.
Ultimate stress	...	...	...	68.2 tons per square inch.
Elastic limit	...	...	...	25.0 tons per square inch.
Elongation per cent.	...	...	...	51.0
Reduction of area per cent.	...	...	...	39.5

The combination of low elastic limit and high ductility has this disadvantage that manganese steel is prone to flow under stress. It does not possess high resistance to compression or to continually repeated blows of a hard mineral, which will gradually batter it out of shape. Tests of this property made at the Watertown Arsenal, U.S.A., gave the following results :—

TABLE X.

RESULTS OF COMPRESSION TESTS OF CAST MANGANESE STEEL.

No. of Test Piece.	Analysis.				Permanent Set at a Pressure per square inch of				Total Load.
	C %	Si %	Mn %	Cr %	40,000 lbs.	50,000 lbs.	60,000 lbs.	70,000 lbs.	
1	1.23	0.95	12.6	—	0.0006	0.0036	0.0213	0.0981	190,100
2	1.26	0.54	12.8	—	0.0020	0.0046	0.0182	0.0899	180,100
3	1.31	0.43	12.7	—	0.0010	0.0036	0.0204	0.0998	172,300
4	1.22	0.72	11.7	0.86	0.0002	0.0009	0.0038	0.0220	175,200

All the test pieces were cast and finished by grinding to 4 inches long and 1.129 inches in diameter giving 1 square inch of cross sectional area. At the total load the pieces buckled. The permanent set at the pressure of 40,000 pounds per square inch showed that the limit of elasticity had been passed.

What has been called the "Merit number" of an alloy is obtained by multiplying the figure representing its tensile strength with that representing its elongation. This gives a rough idea of the amount of work that must be expended upon the material to break it. Judged by this test manganese steel possesses the highest merit number of any known alloy. Some figures given by Mr. Hibbard are shown in Table XI,

Each of these metals yields to stress within its elastic limit so that some work must be expended on it to strain it up to that point. With a non-ductile metal such as cast iron or even untreated manganese steel this accounts for such small resistance to work as it has. The elongation of 0.5% given in the table for cast iron is high, but its power to absorb energy without breaking is increased by its ability to be strained within the elastic limit. If a material had no ductility and were perfectly rigid the slightest blow would break it. Glass which is not ductile and is very nearly rigid approximates to such a

TABLE XI.
MERIT NUMBERS OF VARIOUS METALS.

<i>Metal.</i>	<i>Tensile Strength. lbs. per sq. in.</i>	<i>Elongation per cent.</i>	<i>Merit Number.</i>
Manganese Steel	140,000	50	7,000,000
Nickel Steel heat-treated ..	207,000	14	2,898,000
Nickel Steel untreated ..	95,000	21	1,995,000
Soft Steel	60,000	30	1,800,000
Tool Steel	130,000	5	650,000
Cast Iron	20,000	0.5	10,000

material. It is easily broken by a blow though it offers considerable resistance to a static load.

The effect of the toughening operation on the merit number of manganese steel is shown by the following results obtained by Hadfield.¹

TABLE XII.
RESULTS OF TESTS OF TOUGHENING OPERATION ON MERIT NUMBER OF
MANGANESE STEEL.

<i>Sample No.</i>	<i>Condition.</i>	<i>Tensile Strength. Tons per sq. in.</i>	<i>Elongation per cent.</i>	<i>Merit Number</i>
1	As forged.	39.3	3.5	308,420
	Toughened.	64.9	50.0	*7,262,000
2	As forged.	36.4	1.56	127,296
	Toughened.	67.0	44.44	† 6,682,440

CASTINGS.

Manganese steel castings are made in dry sand, in green sand and in some instances in iron moulds. Its high co-efficient of expansion has to be reckoned with since it increases the liability of a casting to be cracked or pulled apart by shrinkage or cooling. It requires large sink heads. The design of these castings is an important matter. The mass should be as uniform as possible throughout, and in particular no part should be much thicker than the rest. If a thick part is unavoidable it should be connected with a sink head by metal of the same thickness. Bosses and heavy fillets which are often advisable in iron and simple steel castings should be avoided because of the local increase of the mass they cause.

1. Hadfield. R. A. Manganese in Iron and Steel. Proc. Inst. Civ. Eng., Vol. 93, Pt. 3, 1887-88, p. 1, 16.

* The toughened steel was 24 times as hard to break as the untoughened.

† The toughened steel was 50 times as hard to break as the untoughened.

USES.

Probably no alloy steel has found so many uses as manganese steel. Only some of the more important of these can be touched on. It is largely used in the equipment employed in mining, milling and in the treatment of ores and other mineral products, in quarrying and rock dressing, digging and dredging, in railway tracks, in parts of machines which are exposed to gritty wear and in burglar-proof safes and vaults. Its low elastic limit, however, precludes its use for many other purposes, for which otherwise it would seem to be eminently fitted. When the service required is such that the resistance of the metal to flow is not exceeded, the results are usually excellent, but when for any reason the pressure at the point of wear passes the flow point the results are disappointing. It has been found to be particularly valuable in resisting abrasion under slow speeds of impact as in Blake crushers, rolls, gyratory crushers, and similar machines, but results in high-speed grinders such as the various centrifugal mills are, if not poor, at least such as will not often warrant the expense of manganese steel wearing parts, especially if such parts require some finishing which must be done by slow and expensive grinding. For the same reason it makes good car wheels which are run at slow speeds, such as in mines, but it is unsatisfactory in wheels used on railway cars which are run at high speeds. For railway track work, e.g., cast frogs, switches, curved rails and other special work, it is by far the best steel available. It is probably the best material known for making burglar-proof safes and vaults. It is too hard to be cut and too strong to be broken even by considerable charges of dynamite and nitro-glycerine. The non-magnetic property of this steel has found an important use in the cover plates of lifting magnets for handling heavy iron and steel articles where it is subjected to hard blows from the pieces jumping up to meet the magnets. It is also used in ship structures near the compass since it does not affect the compass needle.

Its properties are even more improved by hot working than those of carbon steels. A steel which has been cast and heat-treated may show a tensile strength of about 36 tons per square inch with 20% elongation, whereas after it has been well worked by forging and rolling and then heat treated, the tensile strength rises to from 60-70 tons per square inch with an elongation of 50% on 8 inches. In this condition manganese steel has found application for purposes for which its "merit number" and consequent large margin of safety makes it particularly reliable. It is used, e.g., in spring hangers on locomotives. Cold work raises its tensile strength and elastic limit rapidly but destroys most of its ductility. Ultimate stress values of 110 tons per square inch can be obtained in this way with an elastic limit of rather over 100 tons. Woven screens of manganese steel bars have been found especially suitable for screening coke. This substance rapidly wears away the metal on which it impinges. Manganese steel screens give a life of the order of 100 times as great as that of plain carbon steel screens. Agricultural implements

made of rolled plates, such as shovels and hoes, offer an inviting field for the use of manganese steel. The largest demand for hot-worked manganese steel, however, is for rails in railroad service. These are rolled in ordinary rail mills and are heat-treated by being quenched immediately after rolling. Some railway engineers think their durability at least five times that of ordinary rails. Their characteristic yellowish tint, due to austenite, always enables them to be differentiated from the grey colour of the ordinary carbon steel rail due to ferrite and pearlite.

CORRESPONDENCE.

INDIAN TARIFF BOARD.

Your issue of the 13th January has an interesting paper and discussion on the above, but I do not observe that any of the speakers refer to the effect of the tariffs on the population of India. The effect of a tariff is generally to increase prices.

The tariff on iron increases the cost of railway material and, therefore, of travelling. The tariff on cotton goods increases the cost of clothing. Many millions of people in India are suffering from semi-starvation, which causes them to die young. When last I looked up the statistics they showed that about four million people a year died from semi-starvation.

The effect of these tariffs is to increase the poverty of the hard-working peasantry.

ARNOLD LUPTON.

NOTES ON BOOKS.

- (1) HUNTERS AND ARTISTS. (2) PEASANTS AND POTTERS. By H. Peake and H. J. Fleure. Oxford: Clarendon Press. 5s. each.

The piecing together of evidence relating to prehistoric chronology, life and culture is one of the most fascinating of humane pursuits. Messrs. Peake and Fleure in the series "The Corridors of Time" follow the best traditions of scholarship in their presentation of the material sifted by them; their maps and illustrations are excellent, and the way the books are produced is most creditable to the Oxford Press.

The historian of culture and the archaeologist, or historian of cultures, have a good deal in common, and these volumes are to be recommended to the general reader as well as to the student. A writer like Spengler naturally assumes knowledge in his readers which they, as naturally, may not have; but whoever cares to generalise about the rise and fall of the various later cultures should know something about the origin and development of the common human civilisation. With this common civilisation each individual may have his contacts; as also he may with the world of ideas and with two and two making four. Spengler's emphasis was on his sense of the entity of each culture; he rather saw the individual as a prisoner of the spirit of the age. But the "Corridors of Time" are not closed to us.

In "Hunters and Artists," which is the second book of the series, we are carried from the appearance in Europe of *Homo Sapiens*, during the Würm Ice Age, down to the fifth millennium B.C., when the spread of the forest had reduced the people of north-western Europe from the status of hunters to that of food collectors. *Homo Sapiens* is traced in his march from the fertile pastures of the Sahara, over the land bridges at Gibraltar and Tunis into Spain and Italy, and later, after the Laufen retreat, into the south of France. This was, perhaps, between thirteen and fourteen thousand years ago, and we cannot help being stirred by the artistic efforts made—the artistic successes achieved—by our ancestors of the Aurignacian days. Though their technique was rough, their inspiration was fresh and their execution strong. That their choice of subjects was influenced by other than aesthetic considerations is most probable. At first they seem to have preferred to portray women, fat women, while later they went in more for images of the animals they hunted for food.

The trend was away from realism towards stylisation, and the representation of human figures, which was mostly in the round in the earlier stages, was later more often effected in relief. A discovery made in 1912, in the cave of Tuc D'Audoubert, proved that late palaeolithic man knew how to model in clay.

The best known artistic remains of these remote precursors are early Magdalenian mural paintings in monochrome and polychrome. There seems to have been a gradual improvement in technique and skill over a long period, which may or may not have remained in suspension for a while during the Solutrean interval; and then, in late Magdalenian times, came a decline.

For, about seven and eight thousand years B.C., nature made, so to speak, a determined counter-attack on man, and thus provoked him—aided, as he no doubt was, by luck—to laying the foundation of a greater security for himself. In Europe the dense forest, accompanied by wild undergrowth, spread upwards from the south-east. Simultaneously in Africa the Sahara was drying up. The resultant movements of population had the very greatest importance for the future. Indeed, between 6000 and 5000 B.C. "the first elements of settled civilisation were evolved." These were: "the cultivation of wheat and barley, the shaping of stone implements by grinding, the making of pottery, the invention of spinning and weaving, and the discovery that ores of metal could be melted and cast in a mould. It seems likely, too, that the erection of permanent houses dates from about the same time."

These steps were not taken by that part of the race which had been trapped in northern Europe by the forest, but among the pioneers of modern culture were the men who had pushed east and north from the Sahara, and those Sumerians who entered Mesopotamia about 4000 B.C. with a well-developed civilisation of their own: for they could weave cloth, they kept cattle and they knew how to write. Actually the first positive evidences of civilisation date from a thousand years earlier. They were found on the site of what was afterwards Susa, and at Badari in Egypt.

P. B.

THE BRITISH JOURNAL PHOTOGRAPHIC ALMANACK. Edited by George E. Brown, F.I.C., Hon. F.R.P.S. London: Henry Greenwood & Co., Ltd. 2s. net.

The British Journal Photographic Almanack, now in its 63rd year, having been first issued in 1866, contains a large amount of information of interest to photographers and 64 gravure illustrations. The book includes chapters on "The World's Work"—a review of the various uses to which photography is put in

modern commerce, manufacture, science, aerial survey, etc.; on snapshots; amateur cinematography; and a section entitled "Epitome of Progress," in which practical hints and notes on new methods and appliances are given. Formulae and instructions for the various photographic processes, including colour photography, are contained in another section, and there is also a list of photographic societies in the British Isles.

GENERAL NOTE.

SECOND INTERNATIONAL CONFERENCE ON BITUMINOUS COAL.—The Carnegie Institute of Technology announces a second International Conference on Bituminous Coal to be held at Pittsburgh, November 19th to 24th. The purpose of the Congress is similar to that of the one held in 1926 by the Carnegie Institute of Technology: to present the results of recent studies of coal bearing on improved methods of utilization and combustion. The programme will include the discussion of the fixation of nitrogen, the manufacture of substitutes for gasoline from coal, complete gasification of coal, high temperature distillation, low temperature distillation, coal tar products, power, smokeless fuel, etc. An invitation is extended to scientists of all countries to take part in this Conference. The President of the Carnegie Institute of Technology, Thomas S. Baker, will visit some of the principal cities of Europe during the months of March and April, 1928, to confer with fuel technologists who may consider the possibility of presenting papers or taking part in the Congress in any other way. President Baker's address after February 25th will be care of the Guaranty Trust Company, 1, rue des Italiens, Paris, where he will be glad to receive correspondence in regard to the meeting. Any inquiries prior to February 25th should be addressed to him at the Carnegie Institute of Technology, Pittsburg, Pennsylvania, U.S.A.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, FEBRUARY 6. Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Business Meeting.
Automobile Engineers, Institution of, at the Merchant Venturers' Technical College, Bristol. 6.45 p.m.
(1) Mr. W. West, "Foundry Work." (2) Mr. C. T. Skipper, "Machining Operations on a Six-Cylinder Block."
Chemical Industry, Society of, at Burlington House, W. 8 p.m. Mr. Francis H. Carr, "Some Problems encountered in making Fine Chemicals."
Engineers, Society of, at Burlington House, W. 6 p.m. Mr. C. H. J. Clayton, Presidential Address on "The National Rivers and their Functions."
Electrical Engineers, Institution of, Savoy Place, W.C. 7 p.m.
Geographical Society, at 135, New Bond Street, W. 8.30 p.m. Mr. T. Alexander Barns, "In Portuguese West Africa."
Royal Institution, 21, Albemarle Street, W. 5 p.m. General Meeting.
Surveyors' Institution, 12, Great George Street, S.W. 8 p.m. Mr. Leonard Crouch, "The Landlord and Tenant Act, 1927."
Transport, Institute of, at the Institution of Electrical Engineers, Savoy Place, W.C. 3.30 p.m. Mr. Raymond Carpmal, "Safety and Speed on Railways,"

Victoria Institute, at the Central Hall, Westminster S.W. 4.30 p.m. Rev. A. H. Finn, "The Miraculous in Holy Scripture."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Prince D. S. Mirsky, "The Russian Novel after 1880." (Lecture IV.)

At the London School of Economics, Houghton Street, W.C. 5 p.m. Dr. H. P. Biggar, "The Discovery of Canada from Cabot to Champlain."

At University College, Gower Street, W.C. 2 p.m. Prince Dmitri S. Mirsky, "The Heroic Poetry of Old Russia."

5 p.m. Dr. A. S. Parkes, "The Internal Secretions of the Gonads." (Lecture II).

TUESDAY, FEBRUARY 7. Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m. Wing-Commandr. I. G. V. Fowler, "The Maintenance and Repair of Aero Engines." (Joint Meeting with the Institution of Automobile Engineers.)

Civil Engineers, Institution of, Great George Street, S.W. 6 p.m. Messrs. F. C. Vokes and C. B. Townsend, "Power Gas from Sewage-Sludge at the Works of the Birmingham Tame and Rea District Drainage Board."

Metals, Institute of, at the Engineers' Club, Birmingham. 7 p.m. Prof. Dr. F. C. Lea, "Testing of Metals."

Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. Alexander Keithley, "North Palestine and Syria."

- Royal Institution, 21, Albemarle Street, W. 5.15 p.m.
 Prof. A. P. Newton, "The Settlement of the Dominions, 1783-1870."
 Transport, Institute of, at the University, Bristol. 5.30 p.m. Paper by Mr. C. F. Uwins.
 Zoological Society, Regent's Park, N.W. 5.30 p.m. Meeting for Scientific Business.
- University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Sir Bernard Pares, "Russian History from Peter the Great to 1861." (Lecture III.)
 At King's College, Strand, W.C. 5 p.m. Dr. J. A. Hewitt, "Integration in the Nervous System." (Lecture IV.)
 5.30 p.m. Prof. Dr. S. Alexander, "Emergence, or Primary, Secondary and Tertiary Qualities of Things." (Lecture I.)
 At University College, Gower Street, W.C. 5.30 p.m. Sir Henry Slesser, "Trade Unions and the Law."
 8.15 p.m. Miss E. Jeffries Davis, "More London Place-Names." (Lecture I.)
- WEDNESDAY, FEBRUARY 8. Civil Engineers, Institution of, Great George Street, S.W. 6 p.m. Sir Arthur Duckham, "The Utilization of Town's Refuse for the Production of Power."
 Fuel, Institute of, at Burlington House, W. 6 p.m. Mr. Stanley Hopkins, "The Use of Thermal Storage in Industry."
 Geological Society, Burlington House, W. 5.30 p.m. Prof. W. J. Pugh, "The Geology of the District around Dinas Mawddwy (Merioneth)."
 Literature, Royal Society of, 2, Bloomsbury Square, W.C. 5.15 p.m. Prof. Dr. F. S. Boas, "Sir Philip Sydney—The Poet and Critic." (Lecture II.)
 Metals, Institute of, at Thomas' Café, High Street, Swansea. 7 p.m. Mr. N. Alau, "Gases in Metals, with special reference to Copper."
 North-East Coast Institution of Engineers and Shipbuilders, at Middlesbrough. 7.30 p.m. Mr. E. Graham, "Some Notes on Ship Construction."
 Public Health, Royal Institute of, 37, Russell Square, W.C. 4.30 p.m. Dr. W. Norwood East, "Some Problems of Forensic Psychiatry."
 University of London, at King's College, Strand, W.C. 5.30 p.m. Mr. Henry Wickham Steed, "The Prelude to the War." (Lecture IV.)
 At University College, Gower Street, W.C. 3 p.m. Signor Camillo Pellizzi, "La Linea del Paradiso." (Lecture IV.)
 4 p.m. Prof. A. V. Hill, "Muscle." (Lecture IV.)
 5.30 p.m. Mr. J. Haantjes, "The Dutch Mediaeval Play, Mary of Nimweghen."
 5.30 p.m. Mr. I. C. Grøndahl, "Norwegian Country Life, Customs and Sayings." (Lecture I.)
 6 p.m. Prof. Dr. A. L. Howley, "Measurement by Index Numbers—Theory and Application to Recent Economic History." (Lecture II.)
- THURSDAY, FEBRUARY 9. Historical Society, 22, Russell Square, W.C. 5 p.m. Anniversary Meeting. Presidential Address by Prof. Dr. T. F. Tout.
 Oil and Colour Chemists' Association, at 8, St. Martin's Place, Trafalgar Square, W.C. 7.30 p.m. (1) Mr. T. Hedley Barry, "Malayan Damars, Part II." (2) Dr. J. J. Fox, "Zinc Chromes."
 Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. T. J. Offer, "Instantaneous Colour Photography in the Theatre."
 Refrigeration, British Association of, at the Institution of Mechanical Engineers, Storey's Gate, S.W. 5.30 p.m. Mr. J. F. Hooper, "The Egg Marking Proposals of the Poultry Advisory Committee of the Ministry of Agriculture and Fisheries."
 Royal Society, Burlington House, W. 4.30 p.m.
 Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Sir William Bragg, "From Faraday's Note Books." (Lecture II.)
 University of London, at Bedford College for Women, Regent's Park, N.W. 5.15 p.m. Mr. Harold Craxton, "A Lecture—Recital on some Aspects of Elizabethan Music."
 At Birbeck College, Bream's Buildings, E.C. 5.30 p.m. Col. H. Rowan-Robinson, "The Military Problems of the North-west Frontier."
 At the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. V. Tchitchovsky, "Social and Economic Conditions in Modern Bulgaria." (Lecture I.)
 At King's College, Strand, W.C. 5.30 p.m. Mr. Ifor I. Evans, "Economic Aspects of Dualism in Austria-Hungary." (Lecture II.)
 5.30 p.m. Dr. F. W. Rogers Brambell, "The Development of Sex, with special reference to recent work on Birds and Amphibians." (Lecture IV.)
 At the London School of Economics, Houghton Street, W.C. 5 p.m. Mr. K. B. Smellie, "Contemporary Critics of Democracy."
 At University College, Gower Street, W.C. 5 p.m. Dr. R. J. Ludford, "Cytology in Relation to Physiological Processes." (Lecture IV.)
 5.30 p.m. Signor Camillo Pellizzi, "L'Estetica del Croce."
 5.30 p.m. Mr. Percy Flemming, "Relics of Monastic London."
 5.15 p.m. Prof. J. E. G. de Montmorency, "Customary Law in the British Empire, Asia and the Pacific." (Lecture III.)
 Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Mr. W. B. Honey, "English Porcelain."
- FRIDAY, FEBRUARY 10. Chemical Industry, Society of, at Burlington House, W. 8 p.m. Mr. H. A. Allott, "Dry Cleaning."
 Malacological Society, at Burlington House, W. 6 p.m. North-East Coast Institution of Engineers and Shipbuilders, at Newcastle-on-Tyne. 6 p.m. Mr. J. E. Southcombe, "Some Contributions to the Theory and Practice of Lubrication."
 Oil and Colour Chemists' Association, at Milton Hall, Deansgate, Manchester. 7.30 p.m. Dr. Stanley Smith, "Nitro Cellulose Lacquers—Recent Developments."
 Physical Society, at the Imperial College of Science South Kensington, S.W. 5 p.m. (1) Dr. Allan Ferguson and Mr. E. J. Irons, "A Simple Graphical Method for the Determination of Galvanometer and Fluxmeter Constants, with a Note on the Measurement of Intense Magnetic Fields." (2) Dr. C. J. Smith, "On a Method of Constructing the Caustic Curve formed by Refraction at Plane Surfaces." (3) Mr. J. C. Hudson, "The Application of Electrical Resistance Measurements to the Study of Atmospheric Corrosion of Metals."
 Royal Institution, 21, Albemarle Street, W. 9 p.m. Prof. B. Melville Jones, "Research on the Control of Aeroplanes."
 Transport, Institute of, at the Lime Street Station Hotel, Liverpool. 6.30 p.m. Mr. David Taylor, "The Law relating to Bridge Maintenance by Railways."
 At the Town Hall, Newcastle-on-Tyne. 5 p.m. Paper by Mr. A. Howell.
 University of London, at Guy's Hospital Medical School, Borough, S.E. 5.30 p.m. Mr. Graham Simpson, "The Surgery of the Kidney and Ureter."
 At the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Mr. Julian Krzyzanowski, "Polish Literature." (Lecture III.)
 At King's College, Strand, W.C. 5.30 p.m. Dr. R. W. Seton-Watson, "The States of the Little Entente." (Lecture II.)
 5.30 p.m. Dr. Edgar Prestage, "The Chronicles of Gomes Eannes de Zurara."
 At University College, Gower Street, W.C. 5 p.m. Mr. C. F. A. Pantón, "Comparative Physiology." (Lecture V.)
 5.30 p.m. Mr. E. J. Holmyard, "Chemistry in Mediaeval Islam."
- SATURDAY, FEBRUARY 11. L.C.C. The Horniman Museum Forest Hill, S.E. 3.30 p.m. Mr. M. A. Phillips, "In the Haunts of the Sea-birds."
 Royal Institution, 21, Albemarle Street, W. 3 p.m. Mr. H. C. Colles, "Musical London (1660-1759)." (Lecture II.)

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*All communications for the Society should be addressed to the Secretary, John Street
Adelphi, W.C.(2.)*

NOTICES.

NEXT WEEK.

MONDAY, FEBRUARY 13th, at 8 p.m. (Cantor Lecture.) H. GOUGH, M.B.E., B.Sc., Ph.D.(Engineering Department, National Physical Laboratory), "Fatigue Phenomena, with special reference to Single Crystals." (Lecture I.)

WEDNESDAY, FEBRUARY 15th, at 8 p.m. (Ordinary Meeting.) CAPTAIN SIR ARTHUR WELLESLEY CLARKE, K.B.E., Elder Brother of Trinity House and a Member of the Council of the Society, "Trinity House: its History and its Work." COMMODORE SIR RICHARD WILLIAMS-BULKELEY, Bt., K.C.B., R.N.R. (Commodore, Royal Yacht Squadron), will preside.

The paper will be illustrated with models of ancient and modern lights.

CANTOR LECTURES.

MONDAY, JANUARY 30th, 1928. DR. ALBERT ERNEST DUNSTAN, D.Sc., F.I.C., F.C.S., delivered the last of his course of three lectures on "The Scientific Foundation of the Refining of Petroleum." On the motion of the Chairman, LIEUT.-COL. SIR ARNOLD TALBOT WILSON, K.C.I.E., C.S.I., C.M.G., D.S.O., a vote of thanks was accorded to the lecturer for his interesting and instructive course. The lectures will be published in the *Journal* during the summer recess.

DOMINIONS AND COLONIES SECTION.

TUESDAY, JANUARY 31st, 1928. LIEUT.-COL. SIR ARCHIBALD WEIGALL, K.C.M.G., in the Chair.

A paper on "Migration in the Empire" was read by the RIGHT HON. LORD LOVAT, K.T., K.C.M.G., C.B., D.S.O., Parliamentary Under-Secretary of State for Dominion Affairs and Chairman, Oversea Settlement Committee. The paper and discussion will be published in the *Journal* on March 16th.

TENTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 1st, 1928. LIEUT.-COL. SIR DAVID PRAIN, C.M.G., C.I.E., M.B., LL.D., F.R.S., in the Chair.

A paper entitled "Modern Aspects of Rubber Cultivation" was read by MR. CHARLES H. WRIGHT, B.A. The paper and discussion will be published in the *Journal* on March 23rd.

 PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

ALLOY STEELS, THEIR MANUFACTURE, PROPERTIES AND USES.

By H. C. H. CARPENTER, M.A., A.R.S.M., F.R.S.,

Professor of Metallurgy, Imperial College of Science and Technology.

LECTURE III.—NICKEL STEELS, NICKEL-CHROMIUM STEELS, NICKEL-CHROMIUM-MOLYBDENUM STEELS.

(*Delivered November 28th, 1927*).

NICKEL STEELS.

Nickel steels have been in use for upwards of 30 years. Chronologically what is usually called nickel steel was the fourth alloy steel to find industrial application. The steels to which nickel is added aggregate a large tonnage. Mr. Hibbard⁽¹⁾ estimates that in 1913, including the nickel-chromium as well as the plain nickel steels, the total amount of steel produced to which nickel was added, was about 150,000 tons of which about 50,000 tons were plain nickel steel. Figures of present-day production cannot be given but inasmuch as there is a tendency to substitute the cheaper, and in many cases better nickel chromium steels for plain nickel steels, it may be that the production to-day is less than in 1913.

The most marked characteristic of nickel steels is the wide range of composition over which alloys of industrial usefulness have been found to exist. The compass is indeed greater than that of any other class of alloy steels. It ranges from 2% to 74%. The addition of less than 2% does not seem to give enough benefit to make the addition worth while. Speaking generally, nickel in ordinary nickel steel (untreated) raises the tensile strength and, in a still greater proportion, the elastic limit for a given content of carbon without sensibly diminishing the ductility. It is this property which more than any other determines the special application of nickel steel to practical uses.

The effect of the addition of nickel on the inversions of plain carbon steels was fully dealt with in Lecture I. and need not be repeated here. Attention may be drawn to one other aspect of this matter which has not so far received mention. Nickel and iron possess the property of mixing readily in the fluid state. Their melting points are 1452°C . and 1535°C . respectively. The melting point of any alloy of the two metals lies between these figures and moreover the alloys themselves have a very narrow solidification range. There is little tendency to segregation therefore, either in such alloys or in alloy steels of which nickel is a component. This is undoubtedly a valuable property since it makes for homogeneity and uniformity of properties in these steels.

MANUFACTURE AND WORKING OF NICKEL STEELS.

Nickel steel containing from 3% to 4% of nickel is produced in the open-hearth furnace. The nickel may constitute a part of the original charge or it may be added in the metallic form at any time long enough before the heat is cast for the metal to be melted and thoroughly incorporated with the charge. At steel-melting temperatures nickel is negative to iron. The latter therefore protects it from oxidation and even reduces its oxide so that it is not wasted to any considerable extent in melting and working, even when iron ore is added to the bath. It gives no aid in rendering steel sound or free from blow-holes. It does not decompose carbon monoxide or keep the hydrogen or other gases in solution. The steel is indeed liable to have seams and surface defects after it has been rolled and this militates against its wider use. The function of nickel is merely as an alloying element added to improve the physical properties of the finished steel, either in its natural or heat-treated condition. In this respect it must be held to be inferior to manganese (see Lecture II. p. 291).

Nickel steels, low in nickel, can be worked hot by the usual forging and rolling operations just as in the case of a carbon steel. The higher nickel steels, however, require special care in working since they have narrower ranges of temperature within which they may be worked without showing signs of red shortness. Although, as just stated, molten iron protects molten nickel from oxidation, solid iron does not protect nickel from oxidation when scale is formed on nickel steel in the heating furnace. This scale is liable to give a good deal of trouble. It sticks much more firmly to the metal than does the scale of a plain carbon steel, whether hot or cold, and requires special measures for its removal. Articles such as plates, having large flat surfaces from which scale cannot escape even if loosened by such means as rolls or the flat dies of the forging press, are sometimes cleaned cold by electrically driven machines which break up the scale by a shower of blows with chisels or hammers. A round article can be satisfactorily cleaned by the forging operation since the metal is worked while in contact with the dies and the scale is thereby loosened and falls off. It naturally escapes more easily from the under side of the rolled plate than

from the top, and some mills are equipped with apparatus for reversing the plate before it is finished so that the scale which has been repeatedly loosened and then rolled in again can drop off when loosened from the under side.

"Nickel steels are liable to contain seams which appear as dark coloured lines in the metal. The seams doubtless come sometimes at least from "skin" gas holes which become oxidised on their walls and although such oxidised holes will if present form seams in any steel, they seem to persist more in nickel steels perhaps because the nickel prevents the welding of such holes, as may happen with holes in simple steels, if they are squeezed together while hot enough and the walls are clean and not oxidized. A hole near the surface in nickel steel might conceivably therefore be drawn out and the slit formed be opened to the air by the hot working, then oxidized on its inner surface, and form a seam, when a similar hole in simple steel would be welded and therefore not form a seam. Nickel steel ingots should therefore be more sound and free from gas holes. It is held by some persons that seams develop in rolling without being caused by gas holes, and that this tendency is lessened on rolling at a high temperature, about 1300°C." (1).

SOME USES OF NICKEL STEEL.

Nickel steels low in nickel are principally used for structural purposes. The bulk of such steels contain between 2% and 4% of the metal and the alloy most frequently employed contains 3.25%. When nickel steel is mentioned without any further specification it is usually this alloy which is meant. It has a high value for structural purposes such as bridges, gun forgings, machine parts, engines and automobile parts and any similar line of service which is too severe for simple steels.

The bridges in which it is used are particularly those of great span. In such cases the steel is nearly always used in the natural, i.e., unheat-treated condition, in which case the additional strength and ductility imparted is that due merely to the presence of nickel in the metal. Bridge steels of this character constitute the principal exception to the almost universal practice of using alloy steels in the heat-treated condition. It is true that some nickel-steel tension bridge-members have been heat-treated by heating and quenching, being immersed in water edgewise with the longitudinal axis horizontal and afterwards given a second heating so as to produce an elastic limit of about 24.5 tons per square inch. In such cases not more than 2% of nickel is required. The elastic limit just given, however, is rather low. The use of nickel steel has the advantage of saving some weight and this is important in bridges of large span. When, however, the span is moderate a bridge of carbon steel may be just as good and is less costly even though it contains considerably more weight of metal.

1. Hibbard, loc. cit., page 44.

Steel with 2% of nickel is used in seamless tubes e.g., for bicycles and for other equipment which requires a high-grade tube. It is not heat-treated but is cold drawn and used in the work-hardened state.

Gun steel contains 3.5% of nickel and is always heat-treated. This steel is also used in many automobile parts since the variety of properties obtainable by modifying its heat treatment render it fit for almost any service demanding a strength and security from breakage which a carbon steel will not meet. In some large dynamos the revolving fields are connected by nickel-steel rings containing 3% of nickel. This alloy is particularly well suited for this purpose on account of its strength and magnetic efficiency. Its permeability is high and the hysteresis losses low.

Nickel steel rails usually containing about 3.5% of nickel have been tried by several Railway Companies but are generally considered unsatisfactory. They are, however, used to a limited extent in tunnels and other unusually wet or damp places, partly on account of their ability to resist rusting and partly because they are tougher than carbon steel rails. Their price is nearly twice that of carbon steel rails. They sometimes give three times the service but their average life has been much less than that.

The foregoing steels all possess "pearlite" structures. They are mixtures of nickeliferous ferrite and pearlite which have undergone the gamma to alpha iron and iron carbide inversion at a rather lower temperature than in plain carbon steels. The lowering is probably something of the order of 70°C., i.e., to about 630°C. The improved mechanical properties of such steels are due to two reasons (1) the increased strength of nickeliferous ferrite as compared with pure ferrite and (2) the refining of crystal structure produced by the addition of nickel. These steels therefore differ fundamentally in structure and character from those dealt with in the previous lecture, none of which were pearlitic.

Some idea of how the properties of nickel steels of this type can be varied by heat treatment is shown in table XIII, where, except as noted, the elongations were measured on two inches.

It will be seen that a wide range of properties can be obtained making the steels suitable for a variety of structural purposes for which they are not too expensive.

Steels of the "martensitic structure" type find only a very limited application in practice on account of the fact that they are very hard and possess almost no ductility. They are difficult to work either hot or cold but can be rolled if proper care is used. The structural diagram (figure 14, Lecture I.), shows that this particular structure can be obtained from a wide range of compositions. The most noteworthy of these, judged from a scientific standpoint, is the 13% nickel alloy containing 0.55% of carbon discovered by Arnold and Read.^(*) This seems to possess the highest strength of any nickel steels, the value for

¹ Proc. Inst. Mech., Eng., March-May, 1914, pp. 223-279.

TABLE XIII.
PROPERTIES OF NICKEL STEELS.
(3-3.7%) containing Carbon 0.25-0.40%.

Composition. per cent.			Condition	Physical Properties.				Ball Hard- ness.
C	Mn	Ni		Tensile Strength.	Elastic Limit.	Elonga- tion.	Contraction.	
				Tons per sq. in.	Tons per sq. in.	Per cent.	Per cent.	
0.28	0.57	3.44	Natural state.	42.6	25.3	¹ 21.2	30	—
0.40	0.64	3.43	Annealed.	44.1	23.0	² 12.4	33	—
0.40	0.55	3.70	Annealed.	41.6	25.0	³ 15.8	40	—
0.20	0.65	3.5	Annealed.	—	19.0	27	62	170
0.20	0.65	3.5	⁴ —	—	42.4	20	72	216
0.20	0.65	3.5	⁵ —	—	62.5	14	61	330
0.30	0.65	3.5	Annealed	—	28.1	27	63	163
0.30	0.65	3.5	⁶ —	—	38.9	25	68	207
0.30	0.65	3.5	⁷ —	—	55.0	15	57	269
0.30	0.65	3.5	⁸ —	—	83.5	13	57	405
0.25	0.74	3.55	⁹ —	92.4	79.0	14	60	395
0.25	0.74	3.55	¹⁰ —	60.2	50.2	20	67	267

¹ In 8 inches.

² In 18 feet.

³ In 18 feet.

⁴ Quenched in water at 850° C.

⁵ Quenched in water at 800° C. Tempered in air at 316° C.

⁶ Quenched in water at 800° C. Tempered in air at 593° C.

⁷ Quenched in water at 800° C. Tempered in air at 399° C.

⁸ Quenched in water at 800° C. Tempered in air at 316° C.

⁹ Quenched in water at 843° C. Tempered in air at 316° C.

¹⁰ Quenched in water at 843° C. Tempered in air at 538° C.

the ultimate stress being about 87 tons per square inch with an elongation of 12% on two inches. This gives a "merit figure" of about 2,300,000. It is very high for such a hard steel though it does not compare with the 7,000,000 of forged manganese steel. Moreover, it is so hard as to be unmachinable and in this case the authors were unable to drill it for analysis. The composition quoted is synthetic. Arnold and Read point out that it very nearly corresponds to the formula Fe₇Ni. Nickel-martensitic steels in small sections can be rendered austenitic and ductile by water quenching. There is, however, no object in doing this because the same results can be got more cheaply from nickel-chromium steels.

High nickel steels containing 25% or more of nickel and of low carbon content are "austenitic" in structure at the ordinary temperature. In

the natural state they are much softer and tougher than the martensitic steels. Actually their structure is very similar to that of manganese steel, the only difference being that the former shows no signs of twinning whereas in the latter twins are usually observed. This is, however, purely a crystallographic difference. In spite of this close resemblance it is interesting to find that nickeliferous austenite does not possess the special properties which make manganiferous austenite so valuable. It is true that it has a general resemblance, and is a steel of the same type, but the characteristic properties of manganese steel are absent from it showing that even in alloys of closely similar structure the specific influence of the alloying element makes itself profoundly felt. One curious property of a nickeliferous austenite was observed by Hadfield, Longmuir, and the writer.⁽¹⁾ The composition of this steel was nickel 19.91%, carbon 0.41% and manganese 0.96%. Such steel as cast has a pure Austenite structure, is quite soft and tough, and is not magnetic. When machined, however, or worked in any way in the cold it became ferro magnetic, extremely hard and martensitic in structure. This steel was very near to the austenite-martensite boundary and passed from one to the other on being worked.

The high-nickel steels are costly on account of their large nickel content but in spite of this they find certain applications on account of the valuable properties of the alloys. Steel containing from 24% to 32% of nickel in the form of wire has been used for electrical resistance. An alloy with 27% of nickel has found application in bits, stirrups and spurs in riding harness on account of its resistance to rusting. The steel with 30% of nickel has been used for boiler tubes, particularly in marine boilers for which it is admirable. They do not require to be heat-treated. They resist corrosion much better than carbon steel tubes and last about three times as long. The alloy containing 36% of nickel is known as "invar." It is used for making clock pendulums, rods for measuring instruments, and such parts for which its very slight expansion and contraction within the atmospheric range of temperature give it a particular value. The coefficient of expansion though small is not negligible, and compensating devices must be used in invar clock pendulums and the balance wheels of watches. Some invar has a coefficient of expansion as low as 0.000008 per degree C. Samples have indeed been made which contract slightly when warmed. The coefficient given indicates an expansion of 0.05 of an inch in a mile per degree C. When invar is heated to about 300°C. and above, its coefficient of expansion is greatly increased and its lack of expansion at ordinary temperatures appears to be merely a belated and not a destroyed function. With excessive cold also there is a resumption of contraction.

46% nickel steel with 0.15% of carbon is known as platinite. This has about the same coefficient of expansion as platinum and glass and for that

1 Seventh Report Alloys Research Committee. Proc. Inst. Mech. Eng., 1905, pts. 3 and 4, pp. 857-1041.

reason may be embedded in glass without breaking the latter by a difference in expansion. It was at one time used in leading wires into the glass bases of electric incandescent lamp bulbs as a substitute for platinum. It has not, however, been found wholly suitable for this purpose and is not now so used.

The investigation of the magnetic transformation of iron-nickel alloys of low carbon content has resulted in their being grouped into two classes:—
(a) Up to 25% of nickel the change point is rapidly lowered on cooling and at this percentage of nickel it has fallen from 768°C. to below the ordinary temperature. The alloys exhibit an increasing degree of hysteresis with increase of nickel. In the case of the 25% steel it amounts to 620°C. On cooling this steel becomes magnetic at -40°C. If it is then heated it remains magnetic up to 580°C. Steels of this class accordingly are termed "irreversible." At any given temperature within the range quoted they may exist either in the magnetic or non-magnetic condition according to their previous treatment.

(b) Above 25% of nickel the hysteresis of the magnetic change in no case exceeds 100°C. The transformation rises to a maximum at 70% of nickel (550°C. on cooling, 590°C. on heating). It then falls to the magnetic transformation of nickel itself (342°C. on cooling). These alloys accordingly are termed reversible. The phenomena are illustrated in Fig. 18 which is due to Osmond.

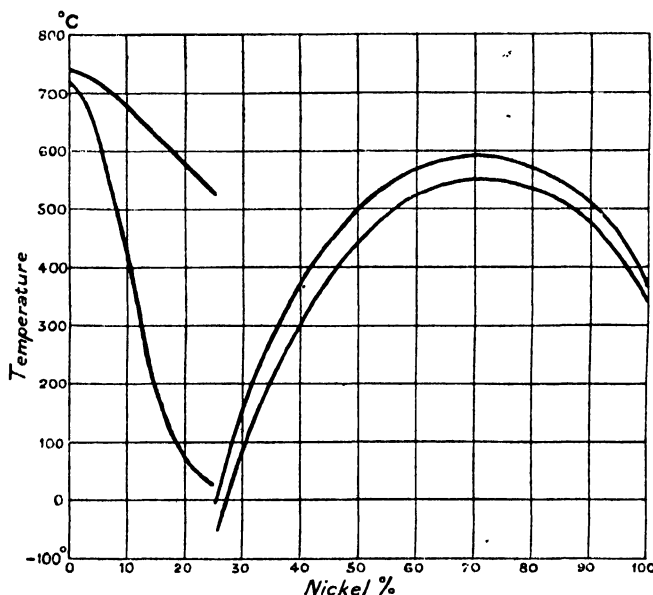


FIG. 18.—Magnetic Transformation Points of Nickel Steels (Osmond).

The very large hysteresis effect exhibited by the irreversible nickel steels indicates that there is a large interval between the transformation temperature on cooling at ordinary rates and the equilibrium temperature. It is only

possible therefore by exceptionally slow cooling to obtain equilibrium structures. In this way Benedicks has succeeded in obtaining the structures of the constituents of meteoric iron, viz., kamacite, taenite, and plessite.

Mention must be made of the remarkable results obtained with a new alloy used in the construction of submarine cables, which consists mainly of nickel and iron with certain quantities of copper and manganese. The range of alloys developed for this class of work contains from 50 to 74% of nickel, from 20 to 25% of iron and about 5% of copper and less than 1% of manganese. Freedom from carbon is one of the primary essentials of these alloys, and they are manufactured in high-frequency induction furnaces, which have so far proved to be the only suitable melting equipment. Alloys can be made in this way in which it is claimed that the carbon does not exceed 2 parts in 10,000.

Two of the best known alloys of this type are "permalloy" and "mumetal" (so called because the Greek letter μ is the symbol for permeability). By their use the speed of signalling on long-distance submarine cables has been raised from a maximum of 300 letters per minute for the old type cable to 1800, with the continuously loaded cable. This performance was obtained on a cable from the Azores to the United States, and has given an entirely new aspect to the economics of submarine cabling which, coupled with the secrecy and reliability of this form of transmission has caused extensive demands for a larger production of this remarkable series of alloys.

A typical mumetal alloy has the following composition :—

Nickel	74.0
Iron	20.0
Copper	5.3
Manganese	0.7

It has a magnetic permeability of about 7,000. The characteristics chiefly required in these alloys are low hysteresis loss, with a very high permeability at low magnetising forces. The composition may be varied according to the type of cable which it is proposed to use and the annealing may be adjusted to give (a) maximum neutral permeability, (b) maximum permeability at magnetic saturation or (c) high or low fields for magnetic saturation.

In certain types of cable an increase in electrical resistance of the alloys is desirable and, in this case, another element which may be tungsten, chromium, silicon, vanadium, molybdenum or aluminium may be added in small quantities.

NICKEL-CHROMIUM STEELS.

Nickel-chromium steels, which are generally known in the trade as chrome-nickel steels are among the most important of all structural alloy steels. Their field of usefulness is continually being enlarged, not only by their application for new purposes, but also by their encroaching on the uses of some other alloy steels, notably of plain nickel steels. Moreover they have almost wholly displaced nickel-vanadium and nickel-chromium-vanadium steels which were

in considerable demand some years ago. The production of nickel-chromium steels amounted in 1913 to at least 100,000 tons of ingots, all of which were made in the open-hearth furnace with the exception of from 2000 to 3000 tons manufactured in crucible and electric furnaces. They are almost invariably used in the heat-treated condition for they are eminently susceptible to the proper heat treatment. The mechanical properties of such steels can be varied within very wide limits. An important feature in their favour is the fact that they can be made more cheaply than a plain nickel steel of the same strength and ductility. They can be obtained in a condition possessing great resistance to alternating stresses and are therefore very suitable for moving parts of machinery, e.g., crank shafts, particularly where the requirements are severe as e.g., in aero engines.

THE COMBINED EFFECT OF NICKEL AND CHROMIUM ON THE CHANGE POINTS OF CARBON STEELS.

It has been shown that nickel both lowers the γ to α and carbide transformation point and increases the hysteresis of carbon steels, while chromium raises the carbide transformation point but also tends to increase the hysteresis. The combined effect of the two metals is not purely additive but a good deal more complex. It has been the subject of numerous investigations in recent years, particularly at the hands of Messrs. Greaves, Jones and Griffiths at the Research Department, Woolwich Arsenal and Professor Andrew and his pupils at the University of Glasgow. The matter can only be briefly dealt with in this lecture and for full information the original papers must be consulted.

Put broadly the dominating factor in the equilibria of nickel chromium steels is the extent to which the nickel and chromium when present together produce both a lowering of the change points and a marked degree of hysteresis. This is due essentially to the time required for equilibrium to be reached in any given alloy. The subject can be illustrated by some typical cooling curves of nickel-chromium steels published by Andrew, Fisher and Robertson.⁽¹⁾

Curves 1, 2, and 3 are typical of the results obtained in hypoeutectoid nickel-chromium steels by varying the initial temperature. Such steels contain some free ferrite.

Curve 1, is obtained by cooling from just above the A_{c1} point in heating. The alloying elements have dissolved in the austenite but no diffusion to any marked extent has taken place. On cooling the A_{r1} change takes place at about 630°C. This probably represents a transformation of the areas rich in carbon and probably also in chromium since the carbide contains chromium as well as iron. Here therefore both the γ to α change and carbide formation have occurred. As compared with a pure carbon steel the lowering of the

1. The Properties of some Nickel-Chromium-Molybdenum Steels. Iron and Steel Inst., May, 1927.

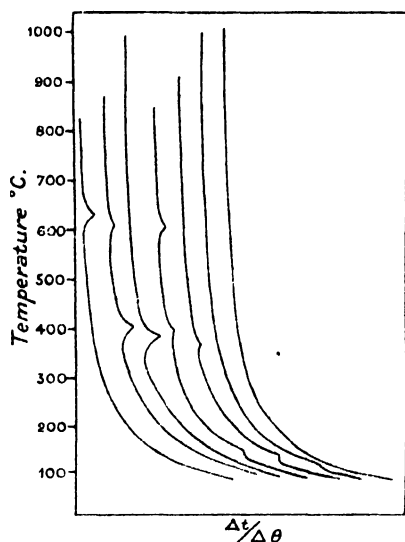


FIG. 19.—Typical Cooling Curves of Nickel-Chromium Steels.
(Andrew, Fisher and Robertson).

temperature of the change is nearly 100°C . The structure of this alloy is a mixture of ferrite, containing most of the nickel, and pearlite (sorbite) containing most of the chromium.

Curve 2, is obtained by cooling from a somewhat higher temperature. In this case partial diffusion has occurred and on cooling two change points are observed. The upper point which occurs at about 600°C . is the same as in Curve 1. The lower point which, is the larger of the two occurs at about 400°C . This corresponds to the γ to α change and the formation of a mixed sorbite and martensite structure. Curve 3, is obtained by cooling from a still higher initial temperature. Complete diffusion of both the chromium and nickel has occurred and only one change point is observed on cooling, viz., at about 380°C . In this case therefore only the γ to α change occurs and the structure is purely martensitic.

Curves 1, 4, 5, 6, and 7, are typical of the hypereutectoid nickel-chromium steels. Curve 1, is the same as in the hypoeutectoid steels, and is obtained by cooling from the same temperature, and the explanation is the same as in that case.

Curve 4, is obtained by cooling from a temperature rather higher than Curve 1. Partial diffusion occurs in this case and no less than three change points are observed on cooling. According to the explanation of Andrew, Fisher and Robertson, the upper point at about 600°C . is due to the transformation of areas rich in carbon and the precipitation of a carbide containing chromium. The intermediate point at 400°C is caused by the inversion of areas rich in alloying elements but poor in carbon. The lowest point, a new one occurring

at about 150°C., is due to an inversion in areas of uniform concentration of all the elements. The topmost inversion produces a pearlitic (sorbitic) structure while those at about 400°C. and 150°C. produce a martensitic structure.

Curve 5 is obtained by cooling from temperatures still higher than in Curve 4. Diffusion is well advanced but is not complete. The topmost point has disappeared; only the two lower points remain.

Curve 6 is produced by cooling from a still higher temperature and here it will be seen that only the lowest transformation point remains. This corresponds to a uniform diffusion of the alloying elements in the steel. The structure obtained is purely martensitic.

The final Curve 7, which is only obtained when the concentration of the alloying elements is high and diffusion is complete, shows no transformation points at all. In other words, even the γ to α transformation in such steels is inhibited and the steel is austenitic.

Accordingly the structures of such steels may be made to vary enormously according to the temperature from which they are cooled and the rate of cooling. They may be composed of (1) ferrite (nickeliferous) (2) chromiferous pearlite (including sorbite and troostite) (3) nickeliferous and chromiferous martensite and (4) nickeliferous and chromiferous austenite.

COMPOSITION AND PROPERTIES.

Although a number of nickel-chromium alloys find application in practical use, the range of their composition is not wide. The upper limit of nickel in the useful steels is about 4.75% but in the majority of cases it is as low as 1.25%. The chromium content is even lower and does not exceed 1.5%. One of the most frequently used steels contains 0.6% of this element. The carbon is usually from 0.2% to 0.3%, manganese from 0.3% to 0.4%, silicon from 0.1% to 0.2%, while neither sulphur nor phosphorus should exceed 0.04%.

Many of the services required of these steels are severe and it must be frankly stated that the standard of manufacture is not in all respects satisfactory. The greatest difficulties experienced are:—(1) a variable standard of cleanliness due to the presence of slag, (2) the presence of roaks, laps, cracks, flaws and surface defects, and (3) the liability of these steels to crack on hardening and tempering. All three defects are essentially bound up with the technique of manufacture of the steel. It appears to be the general experience that if steel is made in the electric furnace it is cleaner and gives better mechanical properties than when manufactured in the open-hearth furnace. The severest demands on this steel are in connection with the manufacture of parts of aero-engines and in these cases special methods of inspection of the steel have had to be adopted in order to ensure the highest possible quality of the metal used.

The wide range of properties possessed by heat-treated nickel-chromium steels has led to their extensive application as structural steels, using this term in the widest sense, and this in spite of the fact that they possess a liability

to what is called "temper brittleness." This term was originally applied by Dickenson ⁽¹⁾ to denote the condition induced in these steels by slow cooling from the tempering temperature, which is revealed by a low absorption of energy in the single-blow impact test on notched bars. Such steels when rapidly cooled from the tempering temperatures are however quite tough. So serious a drawback is this tendency to brittleness (since these steels are always used in the heat-treated condition) that it has been the subject of numerous investigations in recent years, which have had for their object the desire to elucidate its cause, for not until this is known can a scientific remedy be applied. Among these may be mentioned those carried out at the Research Department, Woolwich Arsenal, by Dr. Greaves and Mr. Jones under Dr. Moore's general direction ⁽²⁾. Some reference must be made to their work.

In 1919 Greaves published the results of his early experiments. These were carried out on steels of the following composition :—

TABLE XIV.

	A.	B.	C.
Carbon	0.24	0.27	0.27
Silicon	0.20	0.12	0.18
Manganese	0.49	0.43	0.58
Sulphur	0.029	0.027	0.035
Phosphorus	0.022	0.022	0.023
Nickel	3.54	3.71	3.54
Chromium	0.59	0.65	0.77

The steels were made by the acid open-hearth process. A. and B. were hollow forged: ratio of initial to final cross-section 7.5; ratio of initial to final external diameter 2.4. C. was solid forged; ratio of initial to final cross-section 2.2. Various tests were carried out on test pieces machined from these steels and given a variety of heat treatments. These comprised the Tensile test, Brinell hardness determination, Guillery impact figure and approximate Izod figure. One of the characteristics of a steel in the temper-brittle condition is that the values obtained in the Tensile test are generally almost the same as with the same steel in the tough condition. In other words samples treated identically, except that one is slowly cooled and the other quickly cooled from the tempering temperature, give almost identical Tensile tests with very different impact figures. The following table shows this in a striking manner.

Taking as an example A.3, and A.4, with almost the same tensile figures, No. 3 rapidly cooled gives an Izod figure of 70 while No. 4 slowly cooled gives

1. Journ. of the Inst. of Automobile Engineers, 1917-1, Vol. XII, p. 342. *Discussion of paper by Philpot.

2. Journ. Iron and Steel Inst., 1919, No. 2, p. 329 to 348.

TABLE XV.

Steel and Treat- ment.	Elastic Limit. Tons per sq. inch.	Yield Point. Tons per sq. inch.	Maximum Load. Tons per sq. inch.	Elonga- tion. per cent. on 2 in.	Reduc- tion of Area. per cent.	Fracture.	Brinell Hardness Number.	Guillery Impact Figure.		Approxi- mate Isod. Figure. Ft.-lbs.
								Mesnager Notch Kgm.	$\frac{1}{2}$ mm. V-notch Kgm.	
A	1	22	32.8	45.5	49	Fibrous	221	13.4	10.6	73
	2	27	32.8	44.4	55	"	215	7.3	3.4	35
	3	30	39.1	51.8	34	Fibrous	247	12.8	9.4	70
B	4	28	37.4	49.3	39	"	234	3.6	2.2	12
	1	17	30.0	47.6	47	"	236	11.0	7.0	58
	2	15	28.0	45.5	50	"	221	7.9	4.9	39
C	3	26	35.3	48.9	49	"	234	11.5	9.2	62
	4	27	36.1	48.5	36	Fibrous	226	6.2	4.7	29
	3	20	33.9	47.7	50	"	220	7.6	—	37
C	4	20	31.7	47.1	43	"	217	4.2	—	16
	5	25	37.0	48.6	51	"	223	8.2	—	41
	6	27	34.7	46.5	45	"	214	4.3	—	17
C	7	35	43.6	52.4	50	Fibrous	250	2.5	—	6
	8	33	43.1	53.1	34	"	244	7.8	—	39
	9	20	34.1	49.1	32	Fibrous, laminated	226	8.9	—	45
C	15	30	39.1	48.8	44	Fibrous	231	2.4	—	6
	17	29	37.4	47.1	47	"	221	6.2	—	29

TABLE XVI.

Treatment.		Brinell Hardness No.	Guillery Impact Figure.		Approximate Equivalent Isod Figure. Ft.-lbs.
			Mesnager Notch Kgm.	$\frac{1}{4}$ mm. V-Notch. Kgm.	
Steel A.					
A 1	Water-hardened from 850° C., then	..	..	..	73
2	Tempered at 675° for 8½ hours and cooled in water	..	..	..	35
	" " " " " slowly cooled	221*	13.4	10.6	
	" " " " " slowly cooled	215*	7.3	3.4	
3	Oil-hardened from 1000° C., then	..	..	..	70
4	Tempered at 670° C. for 2 hours and cooled in water	..	..	..	12
	" " " " " slowly cooled	247*	12.8	9.4	
	" " " " " slowly cooled	234*	3.6	2.2	
5	Oil-hardened from 1000° C., tempered at 670° for 2 hours	..	..	..	67
6	And slowly cooled to 600° C., then cooled in water	..	..	..	48
	" " " " " 550°	231	12.4	7.8	
7	" " " " " 502°	230	9.3	3.1	
8	" " " " " 446°	239	5.1	2.3	
9	" " " " " atmospheric temperature	233	5.4	2.4	
3	Oil-hardened from 1000° C., tempered at 670° for 2 hours, and cooled in water from 670° C.	234	3.6	2.2	12
10	Then reheated to 450° for 2 hours and slowly cooled	247	12.8	9.4	70
11	" " " " " 508°	248	11.2	7.0	60
12	" " " " " 554°	245	7.0	2.7	34
13	" " " " " 598°	232	6.1	2.5	28
4	Oil-hardened from 1000°, tempered at 670° for 2 hours and slowly cooled	236	7.6	2.2	31
14	Then reheated to 675° and cooled in water	234	3.6	2.2	12
15	" " " " " 600°	228	12.2	11.9	66
16	" " " " " 556°	223	12.4	9.9	67
17	" " " " " 517°	228	8.0	5.2	40
18	" " " " " 500°	223	4.0	2.9	15
	" " " " " 500°	232	4.6	2.3	19

a figure of only 12. The Guillery impact figures of the same two steels show the same striking differences though to a rather less degree. Table XVI shows how the resistance to suddenly applied stress (Guillery and Izod figures) can be made to vary in steel A by variations in the rate of cooling from tempering temperatures.

As a result of this investigation Greaves concluded that :—“(1) Wide differences in the impact figure with almost identical tensile tests can be produced by suitable heat treatment. (2) After hardening every tempering treatment involving a final rapid cooling from 600°C. or above produces good impact figures. (3) Every tempering treatment involving a final slow cooling from a similar temperature produces a considerably lower and often a very bad impact figure. (4) Reheating to a temperature in the neighbourhood of 520°C. results in brittleness whatever the subsequent rate of cooling. (5) Tough steel of this composition can be made brittle by reheating to this temperature or by reheating to any higher tempering temperature followed by slow cooling. (6) Brittle steel can be restored by reheating to between 600°C. and 670°C. and cooling rapidly. These results agree with the assumption that a critical range of temperatures exists in the vicinity of 550°C; above the temperature the tough condition is stable and below the brittle condition is stable.”

The microstructures of nickel-chromium steels of the above composition consist, when the steel is in the thermal equilibrium, of ferrite which contains the nickel dissolved in it and pearlite which contains practically the whole of the chromium combined with the iron carbide. The nickel strengthens the iron and the chromium hardens the carbide. Moreover a further improvement in properties is effected by the natural refining of the structure due to the alloying elements. When such steels are quenched in water from 900°C.—1000°C. (the temperatures employed in heat treatment) the structure is martensitic, i.e., the alloy has undergone only the γ to α change and the whole of the nickel, chromium and carbon are dissolved in the iron, which is mainly the α but may contain some γ phase. The grain structure of the martensite is very fine. The effect of the second heat treatment at 600°C. followed by either quick or slow cooling is to cause some precipitation of the carbon in the form of a double carbide of iron and chromium. In this case, however, the carbide comes out in a very finely divided form either as sorbite or troostite. No differences have as yet been observed between the microstructures of any given steel in the tough and brittle conditions. This is very remarkable when it is remembered that the impact figures as judged by the Izod test may be in the ratio of 10 to 1. It has, however, not been proved that the microstructures are really identical. Difficulties surround the settlement of this question mainly owing to the extremely fine grain of the sorbo-martensite and troosto-martensite structures of which the heat-treated steels mainly consist.

More recently Greaves and Jones have investigated the matter further ⁽¹⁾. These authors measured the susceptibility of a steel to temper brittleness by the ratio of impact figure of a sample rapidly cooled after tempering to that of a sample slowly cooled, the previous history being the same in each case. Two similar samples were oil hardened from 900°C and tempered for two hours at 650°C. One sample was quenched in water after tempering and the other was cooled slowly, the rate of cooling between 600° and 400°C. being uniform and 0.3° per minute. Thus a steel possessing no liability to temper brittleness would give a ratio of 1, whereas a steel possessing liability would give a ratio greater than unity; by so much the greater the more intense its condition of brittleness. The authors showed that the transformation from the tough to the brittle condition at about 500°C. occurs not at a definite temperature but over a range of temperature within which there appears to be equilibrium between the condition producing toughness and that producing brittleness. If two samples of the same hardened and tempered steel, one initially in the tough and the other in the brittle condition, be heated to any temperature within the range for a sufficient time and are then quenched in water they attain to the same impact figure.

The authors also investigated the influence of composition upon liability to temper brittleness and confirmed what Messrs. Sir William Armstrong Whitworth and Company had previously found, that the introduction of molybdenum into a nickel-chromium steel exercises a very powerful influence in reducing and in some cases completely eliminating susceptibility to temper brittleness. Their results are shown in table XVII.

The six steels in question contain molybdenum varying from 0.27% to 0.70%. The contents of nickel and chromium varied somewhat but were within the usual limits. In each case the ratio of the Izod figure obtained at the two rates of cooling was about 1 and only varied between 0.97 and 1.06. Actually in two out of the eight cases the Izod figure after slow cooling was slightly higher than after quenching. No advantage appears to be gained by the presence of more than 0.5% molybdenum.

Greaves and Jones have shown that both phosphorus and manganese increase the susceptibility to temper brittleness and when they are present in any amount beyond a small percentage the increase is very pronounced. Silicon and vanadium have a slight effect in the same direction, but tungsten has no appreciable effect. Molybdenum therefore stands by itself as the alloying element which counteracts the temper brittleness of nickel-chromium-steels.

"Vibrac" steel manufactured by Sir W. G. Armstrong Whitworth & Co. is the best known industrial steel of this type. Its properties have been the subject of a very large amount of investigation. More research, however, will be required before temper-brittleness is properly understood. Even now we

1 Iron and Steel Inst., 1925, No. 1, 231-225.

TABLES ILLUSTRATING MASS EFFECT AND SEPARATION OF FERRITE IN HEAT TREATMENT OF HEAVY SECTIONS, ETC.

			Composition.			Mechanical Properties transverse to direction of forging.			
No.			C.	Ni.	Cr.	Yield Point.	Maxi- mum Load.	Elong- ation	Izod Im- pact Figs.
			%	%	%	Tons	per sq. in.	%	Ft.-lbs.
1	1160	Nickel steel. Oil hardened and tempered. 2in. thick	.36	3.6	nil	32	46	20	26
2	115	Nickel steel. Oil hardened and tempered (high O.H. temp.) 4in. thick	.37	3.6	nil	28	44	22	18
3	1416	Nickel-chromium Steel. Oil hardened and tempered. 2in. thick	.26	3.5	.8	39	48	21	59
4	893	Nickel-chromium Steel. Oil hardened and tempered. 4in. thick	.28	3.6	.5	33	44	21	32
5	4836	Nickel steel. Oil hardened and tempered. Middle of wall 7in. thick ..	.33	3.8	nil	29	46	21	28
6	5066	The same nickel steel, oil hardened and tempered at same temperatures in section 1½in. × ½in.	.33	3.8	nil	58	67	12	19
7	4839	Nickel steel, Oil hardened and tempered. Outside of wall 11in. thick	.42	3.6	0.1	{ 39	51	16	20
8	4840	The same. Middle of wall 11in. thick					32	47	18

This Table has been kindly furnished by Dr. Greaves.

			Composition.				Mechanical Properties transverse to direction of forging.			
No.			C Ni Cr Mo				Yield Point.	Maxi- mum Load.	Elon- gation	Izod Im- pact Figs.
							Tons	per sq. in.	%	Ft.-lbs.
9	5907	Nickel-chromium molybdenum steel. Oil hardened and tempered. Outside of wall 8in. thick ..	0.3	2.5	0.6	0.5	46	55	19	30
10	3320	Nickel-chromium- molybdenum steel. Oil hardened and tempered. Middle of wall 8in. thick ..					44	54	19	27
11		Armour. Fracture	..	C	Ni	Cr				
12	4948	Armour. Surface ..	..	1.1	—	—	Brinell Hardness 650. Marten- site and Cementite.			
13	4951	„ 0.3 below surface	1.0	—	—	—	Brinell Hardness 525. Marten- site and Cementite. Yield. Max. Elong. Izod.			
14	4252	„ 4in. below surface (general structure)	0.3	3.7	1.8	—	29	44	30	66
							Sorbite (showing remains of the original martensitic marking). Brinell Hard- ness 210.			

This Table has been kindly furnished by Dr. Greaves.

know neither its cause nor why molybdenum counteracts it. Until an explanation of these facts is forthcoming no scientific method of preventing it can be said to exist.

By the widespread use of nickel-chromium steels great improvements have been effected in the production of structures for various purposes, especially where the saving of weight or increase of strength or both are important. The most conspicuous examples of these uses are in the automobile and aircraft industries. Heat-treated alloy steels with double or treble the strength of the simple steels they have replaced are now in regular use. In common with other alloy steels they owe a part of their superior properties to the presence

TABLE XVII.

SUSCEPTIBILITY OF ACID OPEN-HEARTH NICKEL-CHROMIUM-MOLYBDENUM STEELS

	C	Si	Mn	S	P	Ni	Cr	Mo
(A)	0.28	0.15	0.48	0.032	0.028	2.45	0.65	0.43
(B)	0.25	0.10	0.49	0.040	0.035	2.84	0.85	0.48
(C)	0.29	0.14	0.48	0.032	0.026	2.47	0.64	0.47
(D)	0.32	0.16	0.55	0.034	0.028	2.37	0.63	0.70
(E)	0.34	0.12	0.44	0.030	0.030	2.39	0.72	0.57
(F)	0.40	0.14	0.63	0.031	0.028	3.54	0.32	0.27
Steel.	Oil-hardened from 900° C.				Oil hardened from 1000° C.			
	Tempered at 650° C. for 2 hours and Cooled.							
	In Water.	0.3° C. per Minute.		Ratio.	In Water.	0.3° C. per Minute.		Ratio.
A	58	57	1.02	57	59	0.97		
B	37	35	1.06	36	37	0.97		
C	65	64	1.02	—	—	—		
D	44	44	1.00	—	—	—		
E	46	44	1.05	—	—	—		
F	39	37	1.05	—	—	—		

of the alloying element, but still more to the heat treatment which is given to them. In automobiles the use of alloy steels does not pay unless the steels are heat-treated since the gain from their use in the untreated state does not compensate for the increased cost.

While the heat treatment of small masses does not present difficulties this is not the case where large steel parts are concerned. These require (as nearly as is practicable) to be uniformly heated, uniformly cooled in quenching and afterwards to be made true to form since the quenching operation, however carefully done, usually leaves them warped or twisted. Success has been achieved in the case of rails which are regularly heat-treated in the Sandberg Sorbitic process. In time, no doubt, means will be found to heat-treat alloy steels used in bridge construction. A compact object like an armour plate though very large may be quenched without unmanageable warping because of its simple shape.

For making small parts which must be true and well finished structural alloy steels are generally heat treated before they are machined and this requirement prevents the use in such parts of steel of the highest strength attainable because it is not commercially machinable. Speaking generally any part which is to have an elastic limit of more than 50 tons per square inch must be heat-treated after having been machined, though certain chromium-vanadium steels with an elastic limit of 70 tons per square inch are

claimed to be commercially machinable. Some makers of structural alloy steels publish for each steel a graph showing the physical properties it will have when hardened and then tempered at different temperatures. The size of the article has a great effect upon the results obtained by any given heat treatment. The larger the size the less good are the properties, though not always in exact proportion. The mass must therefore always be considered in relation to the properties desired and the composition and heat treatments prescribed must be modified accordingly.

A special desideratum for steels used in automobile and aircraft manufacture and, speaking generally, in moving parts of machinery, is the capacity to resist repeated alternating stresses. Steels possessing this property are said to have a high fatigue strength. Heat treatment is particularly important in relation to this property and may be made to increase the durability of such steels in fatigue tests to a remarkable extent.

For automobiles three grades of nickel-chromium steels are used. They are called low, medium and high, according to their contents of nickel or chromium. The carbon content may be varied for each grade within the limits shown in the following table.

TABLE XVIII.
COMPOSITION OF NICKEL-CHROMIUM AUTOMOBILE STEELS.

<i>Grade.</i>	<i>C</i>	<i>Mn</i>	<i>Si</i>	<i>S</i>	<i>P</i>	<i>Ni</i>	<i>Cr</i>
Low	0.20 to 0.40	0.65	Low	0.045	0.04	1.25	0.6
Medium	0.20 to 0.40	0.65	Low	0.045	0.04	1.75	1.10
High	0.20 to 0.40	0.65	Low	0.045	0.04	3.50	1.50

In aircraft steels the contents of nickel and chromium are generally higher. The nickel may be as high as 4.75% and the chromium 1.8%.

It is curious and interesting that nickel-chromium steels are used both in armour-piercing projectiles and the armour plate itself. In thick heavy armour plates (from 6ins. to 14ins. thick) only the face is hardened. An analysis of the body of such a plate gave in one instance nickel 1.4%, chromium 2.0%, manganese 0.32%, carbon 0.33%, silicon 0.06%, sulphur 0.03% and phosphorus 0.014%. The tensile test of a test piece cut from this plate gave an ultimate stress of 45.0 tons per square inch, an elastic limit of 34.6 tons per square inch, an elongation on 2 inches of 24%, and a contraction of area of 60%. Medium armour from 3ins. to 5ins. thick is somewhat similar in composition. It is not face-hardened since it is sufficiently thin to be heat-treated as a whole. In the majority of these steels the proportion of nickel to chromium is of the order of 2 to 1. Chromium-nickel-vanadium steels are also used in the manufacture of such plates.

With regard to projectiles Cubillo⁽¹⁾ cites the following composition:—nickel 2.55%, chromium 0.75%, manganese 0.58%, carbon 0.48%, silicon 0.40%, phosphorus 0.04%. A test piece quenched in oil and afterwards tempered had an elastic limit of 57.8 tons per square inch, an ultimate stress of 67.0 tons per square inch and an elongation of 19%. In certain cases nickel-chromium-tungsten steels are used. In an analysis given by Girod in the discussion on Cubillo's paper, the following figures are quoted:—nickel 4.0%, chromium up to 1.5%, tungsten 0.25%, carbon 0.50%. Nickel-chromium steels are also beginning to be used in railway locomotive construction, e.g., in connecting rods. They also find application for marine purposes. The following is a typical composition:—nickel 1.60%, chromium 0.32%, manganese 0.70%, carbon 0.24%, silicon 0.18%, phosphorus 0.013%, sulphur 0.015%. This shaft was manufactured from a 35-ton ingot, 45 inches in diameter. When finished it was 14.5 ins. in diameter with an 8 in. hole through on the centre line. The ingot after forging was annealed at 866°C., bored, rough turned, heated to 750°C., quenched in oil from this temperature and reheated at 593°C. The averages of tests carried out on longitudinal test pieces were as follows:—elastic limit 22.5 tons per square inch, ultimate stress 37.2 tons per square inch, elongation on 2 inches 26%, contraction of area 60%.

1 Journ. Iron and Steel Inst., 1913, p. 251.

CORRESPONDENCE.

ROAD SURFACES.

I have read with great interest the paper on road surfaces by Major Clements, and the discussion. I was rather surprised to find no reference to the reinforcement of the road bed with iron bars.

Major Clements refers to the corrugation of the road surfaces in some places. I therefore give the following instance, which is to me a unique experience. I may say that I have ridden a push bike over a great part of Europe and the greater part of the British Isles. About 20 years ago I was in the Austrian Tyrol. I rode for some miles along a narrow country road, the surface of which was perfect. It had in places a slightly glazed appearance as if with oil. This road joined another along which we rode, but we found it almost impossible because it was corrugated; the distance from top to top of each rib was not inches but a foot or several feet, and the rib was high, so that it was necessary to ride at a very slow pace indeed. Otherwise the surface of the road was first-class. I saw a huge post motor wagon with solid rubber tyres. It was the only heavy vehicle I saw that day. There was very little traffic on the roads; it was summer time. I felt no doubt that it was the post wagon that corrugated the road. First, there would be a hardly perceptible ripple, but every day the wheels would come down with a bump and so gradually the ripple got deeper. I have ridden many thousands of miles in Europe and Great Britain since that day, but have never again seen anything like it. I suppose that when, as in England, there is a ceaseless heavy traffic, the ripples and corrugations get knocked about and so do not leave the clear mark.

One of the remedies is doubtless the pneumatic tyre, which I noticed in great omnibuses in Potsdam and Christiania, and last year in the County of Durham, and further North.

ARNOLD LUPTON.

GENERAL NOTE.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH—REPORT OF THE BUILDING RESEARCH BOARD FOR THE PERIOD ENDED 31ST DECEMBER, 1926.—The application of modern scientific methods to the study of the problems with which the building industry is continuously faced is likely to prove of immense importance. Evidence of this will be found in the present report, which is an account of the work carried out at the Building Research Station since its formation in 1921, and, more particularly, since the expansion of its activities necessitated its removal to new premises at Garston, near Watford. The work at the Station is organised in two main divisions: "General Research," which is concerned with augmenting the store of knowledge of the fundamental properties of building materials; and "Intelligence and Special Investigations," which is devoted to the solution, so far as possible, of immediate practical difficulties. The programme of General Research is centred round a suggested classification of building materials in terms not only of their basic properties, but also of their actual behaviour. This classification serves at once to facilitate interpretation and correlation of results. One important group—that of materials containing matter in the quasi-solid (colloidal state)—includes timber, mortars, cements, concretes, limes and plasters, and certain stones; they are characterised by the great significance which must be attached to the effects of variations of moisture content. The portion of the report dealing with Intelligence and Special Investigations contains also brief summaries of a number of investigations which have been undertaken during the period under review at the request of Government Departments and members of the building industry. These summaries should be of considerable value to those confronted with similar problems. To enable those interested to keep in close touch with the work in progress, a general report will be published annually. The above-mentioned report may be obtained (price 2s. net) from H.M. Stationery Office, Adastral House, Kingsway, W.C.2.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, FEBRUARY 13.—Automobile Engineers, Institution of, at the Queen's Hotel, Birmingham. 7 p.m. Mr. C. R. F. Engellbach, "Works Re-organisation to Increase Production."
Brewing, Institute of, at the Charing Cross Station Hotel, Strand, W.C. 7.45 p.m. Messrs. W. V. Elwell, W. J. Watkins, and W. G. Harwood, "The Practice and Principles of Bottle Cleansing."
East India Association, at Caxton Hall, Westminster, S.W. 3.30 p.m. Mr. J. J. Nolan, "An Unofficial View of Burma."
Geographical Society, at Lowther Lodge, Kensington Gore, S.W. 5 p.m. Mr. Cyril Crossland, "The Island of Tahiti."
Metals, Institute of, at 39, Elmbank Crescent, Glasgow. 7.30 p.m. Mr. D. R. Tullis, "Further Notes on Aluminium Alloys."
Transport, Institute of, at the Queen's Hotel, Birmingham. 6 p.m. Mr. J. McDonnell, "Passenger Traffic Problems in a large City."
University of London, at the Institute of Historical

Research, Malet Street, W.C. at 5.30 p.m. Prince D. S. Mirsky, "The Russian Novel after 1880." (Lecture V).

At King's College, Strand, W.C. 5.30 p.m. Rev. C. T. Rogers, "Ecclesiastical Music." (Lecture I).

At the London School of Economics, Houghton Street, W.C. 5 p.m. Mr. D. H. Robertson, "Theories of Banking Policy."

At the School of Oriental Studies, Finsbury Circus, E.C. 5.15 p.m. Professor H. H. Dodwell, "Meadows -Taylor."

At University College, Gower Street, W.C. 2 p.m. Professor Dr. R. Priebsch, "The German Heldensaga." 5 p.m. Dr. A. S. Parkes, "The Internal Secretions of the Gonads." (Lecture III.)

5.30 p.m. Dr. E. A. Baker, "George Meredith." (Lecture I.)

TUESDAY, FEBRUARY 14.—Anthropological Institute, 52, Upper Bedford Place, W.C. 8.30 p.m. Professor Dr. F. G. Parsons, "The Increasing Size of the Skull." Automobile Engineers, Institution of, at the Broadgate Cafe, Coventry. 7.30 p.m. Mr. C. R. F. Engellbach, "Works Re-organisation to Increase Production." Colonial Institute, at the Hotel Victoria, Northumberland Avenue, W.C. 8.30 p.m.

Marine Engineers, Institute of, 85-88, The Minories, E 6.30 p.m. Mr. G. S. Irving, "Corrosion of Iron and Steel with special reference to Steam Boilers."

Petroleum Technologists, Institution of, at the Royal Society of Arts, Adelphi, W.C. 5.30 p.m.

Photographic Society, 35, Russell Square, W.C. 7 p.m.

Meeting of the Scientific and Technical Group.

Quekett Microscopical Club, 11, Chandos Street, W. 7.30 p.m. Annual General Meeting. Presidential Address.

Royal Institution, 21, Albemarle Street, W. 5.15 p.m.

Professor A. P. Newton, "The Dependent Empire and the British Commonwealth of Nations, 1870-1926."

Wireless Technology, Institute of, at the Engineers' Club, Coventry Street, W. 7 p.m. Mr. G. Leslie Morrow, "Selectivity and the Regional Scheme."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Sir Bernard Pares, "Russian History from Peter the Great to 1861." (Lecture IV.)

At King's College, Strand, W.C. 5 p.m. Dr. J. A. Hewitt, "Integration in the Nervous System." (Lecture V.)

5.30 p.m. Professor Dr. S. Alexander, "Emergence, or Primary, Secondary and Tertiary qualities of Things." (Lecture II.)

At University College, Gower Street, W.C. 8.15 p.m. Miss E. Jeffries Davis, "More London Place-Names (Lecture II.)

WEDNESDAY, FEBRUARY 15. Asiatic Society, at Burlington House, W. 4.30 p.m. Miss Mildred Cable, "From the End of China's Great Wall to Moscow." (Joint Meeting with the Central Asian Society).

Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Sir E. Owen Williams, "Bridges."

Civil Engineers, Institution of, Great George Street, S.W. 6.30 p.m. Mr. W. T. Shaddock, "New Training Bank at South Haven, Poole Harbour."

Heating and Ventilating Engineers, Institution of, at the Holborn Restaurant, W.C. 2.30 p.m. Mr. Sam Fox, "Welding for Heating Engineers."

Mechanical Engineers, Institution of, at Liverpool, Professor C. J. Hawkes, "The Marine Oil-Engine." (Thomas Lowe Gray Lecture). Joint Meeting with the Liverpool Engineering Society.

At the Grand Hotel, Sheffield. 7.30 p.m. Mr. E. G. Herbert Cutting, "Temperatures: their Effect on Tools and on Materials subjected to Work."

Meteorological Society, 49, Cromwell Road, S.W. 7.30 p.m. 1. Messrs. L. F. Richardson and R. F. Munday, "The Single-layer Problem in the Atmosphere and the Height-integral of Pressure." 2. Messrs. L. F. Richardson, D. Proctor, and R. C. Smith, "The Variance of Upper Wind and the Accumulation of Mass." 3. Dr. John Glasspoole, "The Distribution over the British Isles of the Average Number of Days with Rain during each Month of the Year."

North-East Coast Institution of Engineers and Ship-builders, B. Ibec Hall, Newcastle-on-Tyne. 7.15 p.m. Mr. L. C. Burrill, "Floating Docks."

Public Health, Royal Institute of, 37, Russell Square, W.C. 4.30 p.m. Dr. W. M. Feldman, "Medico-Legal Aspects of Jewish Life."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Mr. N. B. Jopson, "The Early History of the Slavonic Peoples." (Lecture I.)

At King's College, Strand, W.C. 5.30 p.m. Dr. Dixon Ryan Fox, "The Attack on Pro-British History Texts in America."

At University College, Gower Street, W.C. 3 p.m. Signor Camillo Pellizzi, "La Lirica del Paradiso." (Lecture V.)

4 p.m. Professor A. V. Hill, "Muscle." (Lecture V.)

5.30 p.m. Mr. J. Haantjes, "Humour in the Afrikaans Literature."

5.30 p.m. Mr. I. C. Grondahl, "Norwegian Country Life, Customs and Sayings." (Lecture II.)

6 p.m. Professor Dr. A. L. Bowley, "Measurement by Index Numbers, Theory and Application to recent Economic History." (Lecture III.)

THURSDAY, FEBRUARY 16. Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m.

Dr. G. P. Douglas, "Experiments on Model Aircscrews at High Tip Speeds."

Chemical Industry, Society of, at Milton Hall, Deansgate, Manchester. 7.30 p.m. Mr. H. H. Thomas, "An Examination of the Influence of various Factors on the Products of the Carbonisation of Coal."

Chemical Society, Burlington House, W. 8 p.m. (1) Messrs. R. S. Morrell and S. Marks, "Studies in China Wood Oil. Part II.—The Oxidation of b. elaeostearic Glyceride." (2) Messrs. W. M. Madgin, J. B. Peel and H. V. A. Briscoe, "Cryoscopic Evidence of Compound-formation in Mixtures of Organic Liquids." (3) Messrs. H. V. A. Briscoe and J. B. Peel, "The Preparation and Properties of Selenophene, Tetra-bromoselenophene and tetrachloroselenophene."

Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m.

Linnean Society, Burlington House, W. 5 p.m. L.C.C. The Geffrye Museum, Kingsland Road, E. 7.30 p.m. Mr. P. A. Wells, "Hepplewhite and his Furniture."

Royal Society, Burlington House, W. 4.30 p.m. Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Sir William Bragg, "From Faraday's Note Books." (Lecture III.)

Tropical Medicine and Hygiene, Royal Society of, 11, Chandos Street, W. 7.45 p.m.

University of London, at Bedford College for Women, Regent's Park, N.W. 5.15 p.m. Sir Hugh P. Allen, "Bach."

At the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. V. Tchitchovsky, "Social and Economic Conditions in Modern Bulgaria." (Lecture II.)

At King's College, Strand, W.C. 5.30 p.m. Dr. F. W. Rogers Brambell, "The Development of Sex, with special reference to recent work on Birds and Amphibians." (Lecture V.)

At University College, Gower Street, W.C. 5 p.m. Dr. R. J. Ludford, "Cytology in Relation to Physiological Processes." (Lecture V.)

5.15 p.m. Prof. J. E. G. de Montmorency, "Customary Law in the British Empire, Asia and the Pacific." (Lecture IV.)

5.30 p.m. Signor A. M. Bassani, "Giovanni Berchet" (in Italian.)

At the Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Mr. James I.aver, "Costume in the Theatre."

FRIDAY, FEBRUARY 17. Dyers and Colourists, Society of, at Milton Hall, Deansgate, Manchester. 7.30 p.m. Mr. F. Scholefield, "The Standardisation of Fastness of Coloured Textiles."

London Society, at the Royal Society of Arts, Adelphi, W.C. 5 p.m. Dr. Mortimer Wheeler, "Pre-Historic London."

Medical Officers of Health, Society of, 1, Upper Montague Street, W.C. 5 p.m. Dr. G. F. Buchan and Dr. A. F. Cameron, "The Control of Smallpox."

Royal Institution, 21, Albemarle Street, W. 9 p.m. Rev. E. M. Walker, "The University: its Ideals and its Problems."

University of London, at Guy's Hospital Medical School, Borough, S.E. 5.30 p.m. Dr. Graham Simpson, "The Surgery of the Kidney and Ureter." (Lecture II.)

At the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Mr. Julian Krzyzanowski, "Polish Literature." (Lecture IV.)

At King's College, Strand, W.C. 5.30 p.m. Dr. R. W. Seton-Watson, "The States of the Little Entente." (Lecture III.)

5.30 p.m. Kacos Kyriakides, "Social Life in Cyprus in the Middle Ages."

At University College, Gower Street, W.C. 5 p.m. Mr. C. F. A. Pantin, "Comparative Physiology." (Lecture VI.)

SATURDAY, FEBRUARY 18. L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Miss M. A. Murray, "Amulets and Magical Figures of the Ancient Egyptians."

Royal Institution, 21, Albemarle Street, W. 3 p.m. Mr. H. C. Colles, "Musical London (1660-1759)." (Lecture III.)

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FRIDAY, FEBRUARY 17th, 1928

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK.

MONDAY, FEBRUARY 20th, at 8 p.m. (Cantor Lecture.) HERBERT JOHN GOUGH, M.B.E., B.Sc., Ph.D., Engineering Department, National Physical Laboratory, "Fatigue Phenomena, with special reference to Single Crystals." (Lecture II.)

WEDNESDAY, FEBRUARY 22nd, at 8 p.m. (Ordinary Meeting.) H. R. H. HALL, M.V.O., M.A., D.Litt., F.S.A., F.B.M., Keeper of the Department of Egyptian and Assyrian Antiquities, British Museum, "The Excavations at Ur from 1919—1926" (illustrated by lantern slides). LIEUT.-COL. SIR ARNOLD T. WILSON, K.C.I.E., C.S.I., C.M.G., D.S.O., will preside.

ELEVENTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 8th, 1928. J. SWINBURNE, Esq., F.R.S., in the Chair.

A paper on "Theatre Lighting" was read by MR. HENRY D. WILKINSON, M.I.E.E., M.I.Mech.E. The paper and discussion will be published in the *Journal* dated March 30th.

CANTOR LECTURES.

MONDAY, FEBRUARY 13th, 1928. MR. HERBERT JOHN GOUGH, M.B.E., B.Sc., Ph.D., Engineering Department, National Physical Laboratory, delivered the first of his course of three lectures on "Fatigue Phenomena, with special reference to Single Crystals." The lectures will be published in the *Journal* during the summer recess.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

ALLOY STEELS, THEIR MANUFACTURE, PROPERTIES AND USES.

By H. C. H. CARPENTER, M.A., A.R.S.M., F.R.S.,

Professor of Metallurgy, Imperial College of Science and Technology.

LECTURE IV.—SILICON STEELS, CHROMIUM-VANADIUM STEELS. TUNGSTEN-CHROMIUM STEELS. TUNGSTEN-CHROMIUM-VANADIUM STEELS. HEAT-RESISTING STEELS.

(Delivered December 5th, 1927.)

SILICON STEELS.

Although silicon is not a metal it is present to some extent in all commercial steels and is used to a limited extent in making certain types of what are generally classified as alloy steels. Inasmuch as the principal silicon steel is used for structural purposes, its consideration follows naturally on that of the nickel-chromium steels.

Silicon has a very marked effect upon the inversions in iron. (The structural

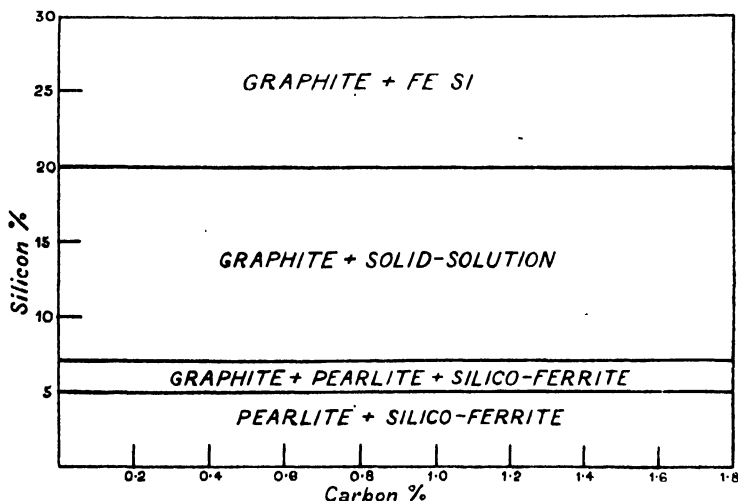


FIG. 20. Silicon Steels. Structural Diagram (Guillet).

Diagram is shown in Fig. 20.) It causes the A_3 change point to become less marked and it disappears at 1.5% of silicon. The A_1 point is raised slightly as the silicon content increases, but, at the same time, it becomes fainter owing to the tendency of the carbon to be precipitated in the free condition (graphite). It disappears finally when the silicon content exceeds 5%. No commercial silicon steel, however, contains graphite.

Silicon steels are generally made in the open-hearth furnace (preferably in the acid) since the acid slag does not waste the silicon in the final additions as rapidly as does a basic slag which contains oxide of iron. Silicon must be added to the charge only a short time before teeming since any oxygen which reaches the metal will be largely taken up by the silicon forming silica. When added to a bath in the proper condition both as regards temperature and the amount of dissolved oxygen or oxides, the silicon overwhelms the gases in solution and the steel as cast is free from blow-holes and with a maximum tendency to pipe. All steels containing from 2% silicon upwards roll very "dry," i.e., they are liable to be cracked by the heavy reductions of the first passage through the blooming mill.

The chief structural use of silicon-alloy-steel is in the manufacture of springs of the leaf type for automobiles and other vehicles. The silicon is considered to make the springs somewhat tougher so that they are less liable to break in service than springs of simple steel. In the trade this steel is usually called silico-manganese steel, though its content of manganese is usually no more than is common in simple steels and is not enough to cause the steel to be classified as a manganese-alloy steel. A paper recently published by Hankins, Hanson and Ford (1) gives details of the properties of one of these steels. Its analysis was as follows :—

TABLE XIX.

		C	Si	S	P	Mn	Cr
Silico-manganese steel	3 in. $\times$ $\frac{3}{8}$ in. plate	0.54	1.95	0.021	0.021	0.94	trace
	1 $\frac{1}{4}$ in. diameter bar.	0.53	2.00	0.022	0.018	0.94	trace

After its change points had been determined 870°C. was adopted for the water hardening and 950°C. for the oil hardening temperature. The quenched steels were free from hardening cracks. Tests were carried out on these materials tempered at 450°C., 500°C., 550°C., and 600°C. The structure of the steel oil-hardened from 950°C. and tempered from 545°C. was mainly sorbitic with traces of martensitic structure. Fig. 21 shows the results of various tests in graphic form of the steel water-hardened at 870°C. and tempered at various temperatures. As compared with other steels tested at the same time, viz., two plain carbon steels and one chromium-vanadium steel, the silicon steel was superior in its fatigue strength and gave, generally speaking, good properties except in the impact (Izod) test. In this particular test the chromium-vanadium steel was markedly superior.

An important use for silicon alloy steel is in the cores of static transformers. With the exception of manganese most of the elements employed in making

1 Journ. Iron and Steel Inst., No. II, 1926, pp. 265-290.

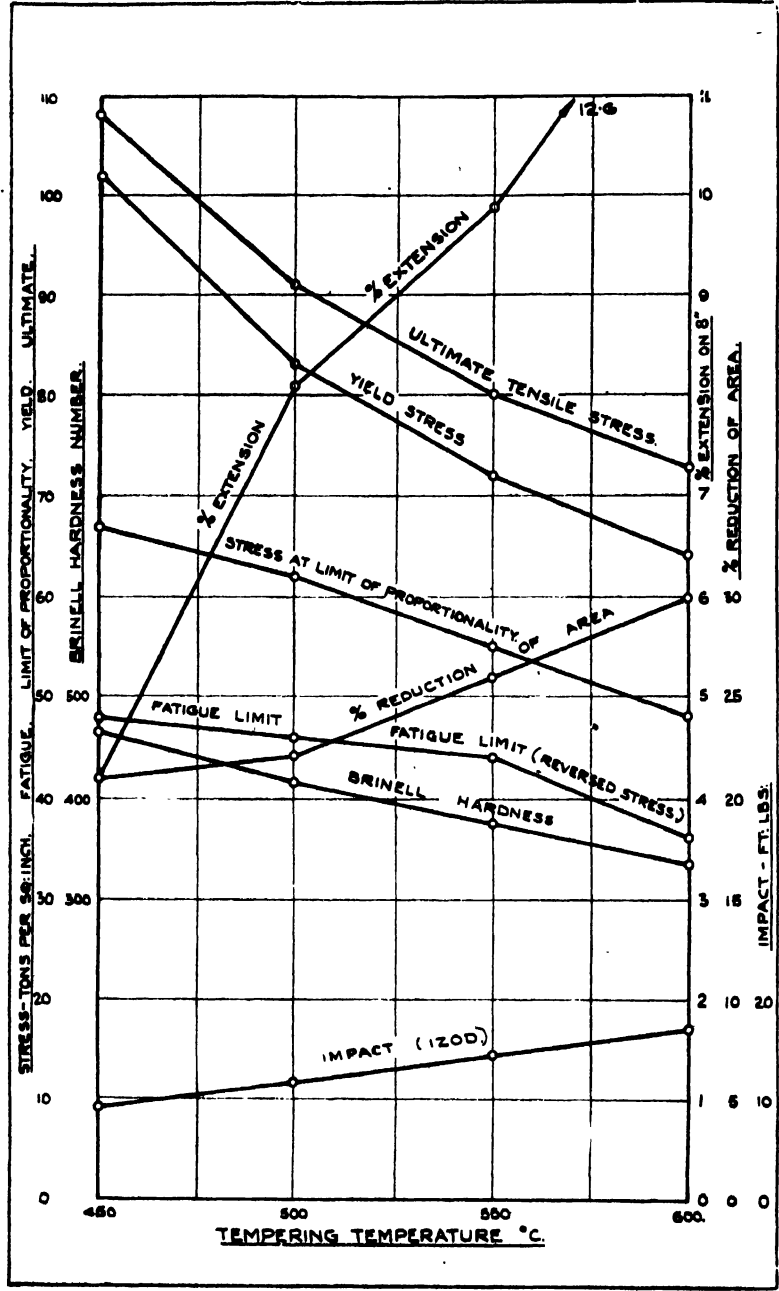


FIG. 21. TESTS ON SILICO MANGANESE STEEL. Water Hardened from 870°C.

alloy steels, although not greatly decreasing the magnetic susceptibility of the iron which contains them, lower its hysteresis loss. Silicon is the element generally used for that purpose because it is cheapest. The content in transformer metal lies between 3.5 % and 4.5 %. The steel is rolled into thin sheets which are of the order of 0.014 of an inch thick. The transformer cores are built up of these which are cut to shape separately by stamping. For low induction the permeability of this steel is nearly as great as, if not greater than, that of any other variety of iron or iron alloy known, and its hysteresis loss is less than that of any other of the same cost. The following is a typical analysis : carbon 0.08 %, silicon 4.18 %, manganese 0.11 %.

CHROMIUM-VANADIUM STEELS.

These steels are usually called chrome-vanadium in the trade. They are a recent development in structural alloy steels and have now an extensive market. In 1913 the production of ingots was of the order of 100,000 tons. It is quite certain that this output is considerably larger to-day. The steels are almost all made in the open-hearth furnace, chromium and vanadium being added in the form of certain alloys before casting. As regards composition the following figures give the ranges usually employed :—

<i>Element.</i>	<i>Percentage.</i>	
Carbon	From 0.25 to	0.60
Manganese	0.36	0.75
Silicon	0.10	0.26
Sulphur	0.01	0.04
Phosphorus	0.01	0.04
Chromium	0.7	1.0
Vanadium	0.10	0.25

From these figures it will be seen that chromium constitutes the major alloy constituent and is usually present to the extent of about 1 %. Vanadium is present in considerably smaller amount and does not exceed 0.25 %.

Hot working of these steels presents no special difficulties. The steel acts in the press and rolls very much like carbon steels with somewhat higher carbon content. The steels are always used in the heat-treated state. They are generally quenched from temperatures in the neighbourhood of 900°C., the quenching agents being either water, oil or air, and are then given a second heat treatment which may be as high as 750°C. or as low as 315°C. By means of these treatments a great range of properties can be obtained. In their physical properties, the chromium-vanadium steels are very similar to the nickel chromium steels, but they have a greater contraction of area for a given elastic limit. It is curious that this higher contraction of area as evidenced in the tensile test seems in some way to be associated with machinability since a chromium-vanadium steel with an elastic limit of 70 tons per square inch may be machined rapidly, whereas a nickel-chromium steel having the same elastic

limit would quickly dull the cutting tool if cut at the same speed. The greater part of the chromium-vanadium steel manufactured goes into automobiles. The steels are preferred by certain makers because of their greater freedom from surface imperfections, notably seams, which nickel steels are prone to have if the ingots are at all unsound. Moreover vanadium tends to remove both oxygen and nitrogen from a steel, whereas nickel does not, so that when present it improves the quality of the steel and the smaller proportion required enables it to compete with the nickel even though its cost is five or six times as great.

Some chromium-vanadium steel is said to be used in armour plate of medium thickness (4 inches). It is not face-hardened but has valuable properties imparted by heat treatment. A similar steel is also used in high-duty forgings and the structural parts of machines. Hibbard⁽¹⁾ gives an interesting example of the use of chromium-vanadium steel. A hydro-electric plant had shafts 6.5 in. in diameter which transmitted 3,000 kw. each at 480 revolutions per minute. These were originally made of untreated nickel steel having an elastic limit of about 18 tons per square inch. These all broke in service. As it was impracticable to make a stronger shaft by increasing the size, other shafts were made under the specification that the elastic limit should be at least 47 tons per square inch with a contraction of area of 40% and a ball hardness uniform within 5%. The composition of the steel chosen was as follows:—Carbon 0.33%, manganese 0.54%, phosphorus 0.022%, sulphur 0.030%, chromium 0.89%, vanadium 0.24%. The ingot 30 x 25 in. in section, was rolled to an 18 x 18 in. billet and the shafts forged from it. These were heat-treated, and the average test of the test-pieces cut from them gave the following results:—elastic limit 47.0 tons per square inch, ultimate stress 56.8 tons per square inch, elongation on two inches 15%, contraction of area 46.2%, ball hardness figures 278, 283, 278. These shafts accordingly met the specifications and proved satisfactory.

Chromium Vanadium steels are also finding application as spring steels. Hankins, Hanson and Ford, in the paper already referred to, give details of tests on a heat-treated chromium-vanadium steel of the following form and analysis.

TABLE XX.

		C	Si	S	P	Mn	Ni	Cr	V
Chromium-Vanadium Steel.	3 in. x $\frac{3}{8}$ in. plate.	0.55	0.29	trace	0.006	0.68	0.10	1.16	0.27
	1 $\frac{1}{4}$ in. diameter bar.	0.53	0.29	„	trace	0.67	0.10	1.15	0.27

It will be noticed that the steel contains a little nickel in addition to the chromium and vanadium. It was tested after oil quenching from 850°C.

¹ Loc. cit., p. 88.

followed by tempering at 400°C ., 475°C ., 550°C . and 600°C . The microstructures were extremely fine and a high magnification was needed in order to show them clearly. Oil quenching from 850°C . gave a martensitic structure. Tempering transformed this more or less into a fine sorbitic structure. The results of the

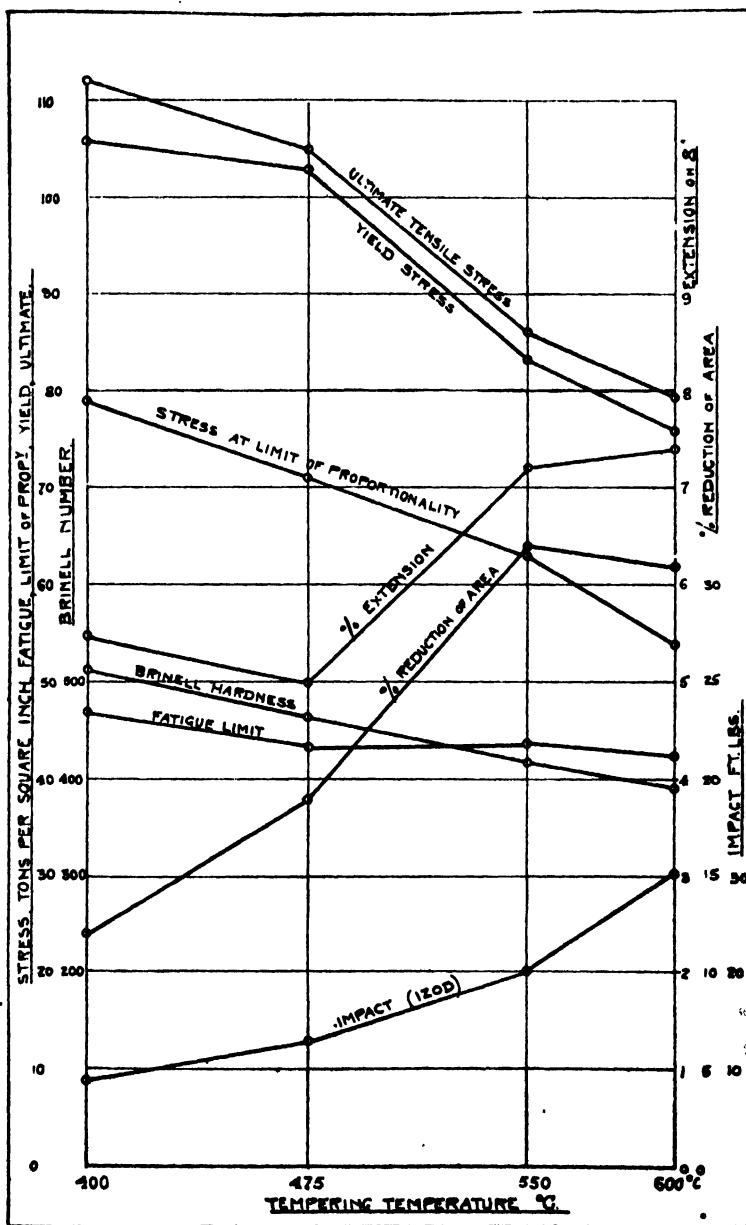


FIG. 22. TESTS ON CHROME VANADIUM STEEL. Oil Quenched from 850°C .

tests are given in Fig. 22. As compared with silico-manganese steel the tests show that with the exception of tempering at 600°C. the chromium-vanadium steel has lower values of fatigue limits than silico-manganese steel of similar tensile strengths or tempers at similar temperatures. Izod values, however, (impact tests), are distinctly superior to those of the other steels. This steel when tempered at 600°C. gives a Brinell number of 400, a good reduction of area, a high Izod value and a fatigue limit of ± 42.5 tons per square inch.

TUNGSTEN-CHROMIUM AND TUNGSTEN-CHROMIUM-VANADIUM STEELS.

As described in Lecture II, Mushet steel, a self-hardening tool steel, was a tungsten manganese steel. If the percentages of carbon and manganese are considerably reduced and either chromium or chromium and vanadium are added, the resulting alloy is also a tool steel, but it possesses even more remarkable properties than Mushet steel. This was the great discovery of F. W. Taylor and Maunsel White in 1900, the originators of what are known as high-speed or rapid tool steels. These steels when subjected to a particular heat treatment were found to possess properties entirely different from those either of carbon tools or Mushet tools. The heat treatment departed entirely from all previous practice. Whereas great care has to be taken not to overheat a carbon steel tool and to a rather less extent a Mushet tungsten-manganese steel in hardening, the tungsten-chromium tool steels introduced by Taylor and White were subjected to a heat treatment in hardening so high that the "nose" of the tool was almost melted. These tools then required a second heat treatment, also at a much higher temperature than a carbon steel tool, viz., from 550°C. to 600°C. After this they were in a condition to work and actually did work at temperatures far above those which would destroy the cutting power either of a carbon steel tool or a Mushet self-hardening tool. Not only did these tools machine the work at a red heat as a result of which they were said to possess the property of red hardness, but they did not exhibit the best cutting properties unless they were used at these high temperatures. On account of this property a tool made of such high-speed steel could be made to cut continuously at speeds from three to five times as great as that practicable with other tools and when as a result of the friction of the chip on the tool the temperature may be 700°C. at the point of contact and the chip itself may be heated to a temperature of about 350°C. As a consequence of this the chips machined from the work in this way are tempered a deep blue on the surface.

The Taylor-White process as worked out at the Bethlehem Steel Company was not a chance discovery. It was the final result of many experiments and years of hard work by Taylor, an engineer, and White, a metallurgist. The full story is told by Taylor in his Presidential address to the American Society of Mechanical Engineers, 1906.⁽¹⁾ Steels treated by this method were shown

at the Paris Exhibition in 1900, where they naturally created a great sensation amongst those familiar with the machining of metals. Since the original patents were issued in 1901 others have been granted for almost every possible combination of elements which were in any way thought to be useful or valuable constituents of tool steel. During the subsequent quarter of a century improvements in detail have been effected, but the Taylor-White process, which consisted partly of a new composition and partly, and even more importantly, of a new heat-treatment, remains essentially unaltered to-day. These steels have in the past quarter of a century worked an entire revolution in the machine shop business of the whole world, permitting largely increased outputs and commensurately lower costs. As a consequence they are now being used very generally and in some shops exclusively for machining iron and steel as well as other metals by cutting operations by machine tools.

COMPOSITION OF HIGH-SPEED CUTTING TOOLS.

After the publication of the original Taylor-White patents and a good deal further experimenting on the part of steel makers, the composition settled down to a basic one of from 0.5% to 0.7% carbon, about 14% of tungsten, and from 3% to 4% of chromium, manganese from 0.15% to 0.50%, silicon from 0.1% to 0.4%, sulphur and phosphorus as low as possible and in any case not above 0.04% each. This steel gave a very good account of itself provided that due care was taken in manufacture, hardening and tempering. The next step consisted in increasing the tungsten and adding vanadium. For many years a high-speed steel has been on the market containing round about 18% of tungsten, chromium from 3% to 5% and vanadium anything up to 2%. This steel has also justified itself as judged by the wide demand for it. Experiments were also made by introducing molybdenum, either to the partial or total exclusion of the tungsten. Molybdenum can undoubtedly be used and is twice as powerful as tungsten, but the steels are a good deal more sensitive to heat treatment and are liable to deterioration. On the whole, therefore, molybdenum has not held its ground. A further development came comparatively recently with the addition of cobalt in substantial percentages of anything from 2% to 6%, the other elements remaining the same. The addition of cobalt increases the cost of the steel, but judging by the demand engineering shops consider that they are getting value for money in paying the higher price of the product. The latest steels therefore are quaternary steels containing tungsten, chromium, vanadium and cobalt, and in some cases small amounts of molybdenum and/or nickel in addition. Inasmuch as these last-named steels also contain some manganese there are present in them simultaneously all seven alloying elements used in alloy steel manufacture. High-speed steels are accordingly by far the most complex of the alloy steels from the point of view of composition, but it is interesting to find that in spite of this the conditions of manufacture are very similar for all such steels and the microstructures of the tools themselves conform to one general type.

The following table gives the range of composition covered by most of the high-speed steels now in existence :—

Range of Composition.

Carbon	...	...	...	From 0.6%	to 0.75%
Manganese	...	...	...	„ Trace	„ 0.5%
Silicon	...	...	...	„ 0.15%	„ 0.4%
Sulphur	...	...	...	As low as possible.	
Phosphorus	...	...	...	As low as possible.	

Alloying Elements.

Chromium	...	...	...	From 3%	to 5%
Tungsten	...	...	...	„ 14%	„ 19%
Molybdenum	...	...	...	„ up	„ 1%
Vanadium	...	...	...	„ 0.5%	„ 2%
Cobalt	...	...	...	„ 2%	„ 6%
Nickel	...	...	...	small	up to 0.3%

Thus a high-speed tool steel may contain anything up to about 30% of alloying elements.

MANUFACTURE AND HARDENING TREATMENT.

High-speed tool steels were originally all made by the crucible process. Gradually, however, this has been displaced by manufacture in electric furnaces. The greater part of the present-day steel is made in this way, the high temperatures attained in the electric furnace permitting good miscibility of the alloying elements with steel. The facts that the unit of production is much larger, and the atmosphere is neutral, thus minimising the risk of contamination by gases, constitute the main advantages which have brought about this change. The steel shows a strong tendency to "pipe" on setting which is checked by the use on large ingots of a hot "dozzle," which is a clay ring preheated red hot placed on the ingot top and filled with molten steel. This arrangement keeps the top of the ingot molten sufficiently long for the "pipe" to be of much diminished size, and nearly, if not quite, all contained within the part of the ingot surrounded by the dozzle. The proportion of the ingot required to be cropped therefore is much reduced. Ingots are usually top poured. The moulds are usually closed at the bottom end and are either made with parallel walls or tapered so that the ingot is larger at the top than at the bottom. The steel as cast in this way solidifies extremely rapidly. It has a coarse structure and rather a dark colour as compared with plain carbon steels of the same carbon content. A corner is broken from the top of each ingot to show the grain, and the ingots are classified by the eye in this way. As a rule, they show a "columnar" structure—an arrangement of crystals whose axes are normal to the cooling surface. This is the original "ingot" structure of the steel and *however much it may be heat-treated and worked by forging, etc., it is never*

completely destroyed and exercises its influence upon the property of the tool made from it. The ingots vary from $3\frac{1}{2}$ in. x $3\frac{1}{2}$ in. to 16 in. x 16 in., but most of them are from 5 in. x 5 in. to 9 in. x 9 in.

Usually they are annealed for some hours at about 850°C . and are afterwards forged at a high temperature. This is required on account of the stiffening influence of the large percentage of alloying elements present, which makes the steel less easy to work. Under these conditions, however, it can be worked satisfactorily under the hammer or press and brought down to the dimensions finally desired. The original heat treatment specified in the Taylor-White process provided for the following operation:—The nose of the tool was heated to incipient fusion (between 1200°C . and 1300°C .) and then plunged in a bath of melted lead at about 550°C . The heating was done in a small furnace over a deep coke fire blown by an air blast so that the atmosphere surrounding the tool was that of carbon monoxide. After it had attained the temperature of the lead it was taken out and placed in an air blast to complete the cooling. Tools which are desired to be specially tough were given a second heating to about 565°C . and then cooled either in the open air or an air blast. The foregoing treatment is now seldom used. In some shops the practice is still followed of heating the tool in a smith's fire to incipient fusion followed by quenching in oil. This has the disadvantage that, though the atmosphere consists essentially of burning carbon monoxide, it is not neutral as far as the heated tool is concerned. It is both oxidizing and carburising. Both these processes change the composition of its surface and any scale produced by oxidation interferes with the transfer of the heat when the tool is quenched in oil. For this reason it is unevenly chilled and consequently unequally hardened.

By far the best method of heat-treating high-speed steels is in a molten bath of salts composed as a rule of chlorides—usually a mixture of sodium and barium chlorides. These baths are electrically heated and the temperature is under proper control. The action of the fused salt upon the tool is inappreciable. Moreover there is the further advantage that when it is taken out for quenching, the tool is protected from oxidation by a thin film of salt which dissolves as soon as it is plunged in water. In this way a clean and uniformly quenched tool is obtained. It is then ready for a second heat-treatment in a molten lead bath at about 600°C . which is required in order to bring it into the condition of maximum cutting hardness. It is important to realise therefore that the tools receive a double hardening (1) that produced by quenching and (2) that produced by reheating.

When Taylor and White first introduced these tools it was thought that the higher cutting speeds, rendered possible, constituted the only benefit to be derived from them and since the higher speeds, although consuming more power roughly in proportion to the increase in speed, did not materially increase the stresses on the machine tools, it was thought that the latter merely needed to be speeded up in order to get the full benefit from the new steels. But it

was soon found that the steels in addition to cutting at higher speeds were capable of taking much heavier cuts which proportionately increased the stresses on the tools. Therefore in order to take full advantage of the heavier, as well as the more rapid cuts, machine tools had to be redesigned to provide the greater strength required, and were supplied with proportionately more power. The resulting economies have been enormous.

The advantages which have accrued from the use of high-speed steels as compared with that of plain carbon tool steels are in the lessened costs of the ordinary operations of finishing iron and steel on account of (1) a more rapid cutting speed (2) heavier chips cut, hence larger cuts and feeds, (3) the saving of power per unit of metal cut off, (4) lower cost of plant for a given output, and (5) lower general overhead charges.¹

As already mentioned, these tools not only cut at a red heat but cut better than they would at the ordinary temperature. The reason for this will be explained presently. Experience has shown that the most advantageous way in which to use them is for "roughing" work, i.e., taking heavy cuts at high speeds. Actually they are not as suitable for finishing cuts as the plain carbon tool steel. The latter keeps a fine edge with a light cut and a slow speed, say, of 20 feet per minute. Under these conditions the high speed steel does not do so well. Therefore in most machining work where high-speed steels are used, the preliminary cutting is done with them and the finishing cut made with carbon tool steel. It is important to realise that the point of the tool does not cut. It only drives open the crack which advances in front of it and a high-speed tool fails through the turnings which impinge upon the top face at a point at some distance behind the cutting edge. These gradually wear away the steel forming a depression *until the cutting edge is actually broken off*. The edge of a rapid steel tool at work is probably never as hot as the metal which is behind it where the heating caused by friction of the chip as it is deflected and rubs hard on the tool is most intense. It is here that the highest temperature of the tool is reached, probably in some cases as high as 700°C. The edge itself is kept relatively cool by the cold metal flowing over it. Two broken tips are shown in Fig. 24.

TESTING THE QUALITY OF HIGH-SPEED STEEL.

More than 20 years ago F. W. Taylor² called attention to the need of a reliable and inexpensive method of testing high-speed steels in order to show their value and quality. Since that date many attempts have been made to devise such a method. Mention should be made in this connection of the work of Herbert³ and Edwards⁴, each of whom has recommended the use of a machine and methods which are designed to satisfy the above conditions. It

¹ Hibbard loc. cit., p. 83.

² Loc. cit.

³ Trans. Manchester Assn., Eng., 1908-1909, p. 302-317.

⁴ Iron Age, Vol. 89, April, 1912, pp. 957-960.

has been found by experience, however, that no test can as yet take the place of a trial under actual conditions of work in any given case, because the performance of a tool under one set of conditions does not enable any prediction to be made as to its performance under another set of conditions. One of the reasons for this is that greater durability is sometimes obtained by a change, i.e., increasing or diminishing the speed of the cut and thus altering the temperature of the tool. Another reason is that a given tool when used at its best speed may be excellent for cutting a certain material and yet prove inferior to another tool for cutting a different material. Physical tests of high speed cutting tools at different temperatures up to about 800°C. are needed to ascertain the effect of heat upon their properties. Until such information has been obtained methods of testing are to a large extent empirical.

In 1910 Herbert¹ made the interesting discovery that high-speed tools and indeed some plain carbon steel tools may have two widely separated cutting speeds at which the tool is more durable than at speeds above, below or between. Thus out of many cases described one tool cooled in an air jet had nearly equal durability at two speeds, viz., 50 and 90 feet per minute, whereas at 65 feet the durability was less than one-half that at either speed. This discovery no doubt accounts for some of the anomalies encountered in tool steels, as well as in other steels the properties or performances of which are not such as would be expected from their composition. Thus a tool may be condemned when an increase of its cutting speed would cause it to give satisfactory service and durability.

THE CONSTITUTION OF HIGH-SPEED TOOLS AND A THEORY OF THEIR HARDENING.

Any theory of the hardening of these steels must accord with and as far as possible explain the following facts:—(1) The steels *require* to be hardened from a very high temperature—in the neighbourhood of 1200°C.—a treatment which would ruin the ordinary carbon tool steel and Mushet steel. (2) After this treatment they are not in the hardest condition of which they are capable. (This also differentiates them from carbon and Mushet steels.) They require a second heat treatment at about 600°C. This produces what is known as secondary hardness. (3) Secondary hardness is the hardest state of which the tools are capable, but only at the temperature in question, viz., about 600°C. (4) The capacity to cut at a red heat is the outstanding and most characteristic property of these steels. It is known as “Red Hardness.”

It should be noted at the outset that in spite of the wide variation in the composition of these steels, (see page 334) their structures in the annealed condition are very similar. They are also very much alike in the hardened condition. The essential alloying elements required are tungsten and chromium, i.e., with these elements present the tools exhibit red hardness. It is to be

¹ Journ. Iron and Stee. Inst., 1910, Pt. I, p. 216.

noted that both of these are carbide forming elements (Lecture I, Table VI). The properties of the tools are improved by having vanadium present. This also is a carbide-forming element. Molybdenum which is sometimes present also falls into the same category. (About cobalt which is present in some of the newest steels information is not as yet available.) Leaving cobalt, therefore, out of consideration it is clear that the alloy elements, all of which have been found valuable and some of which are essential, are carbide-forming elements in the steel. This is a very significant and important fact. In the annealed condition these steels are a mixture of sorbite (pearlite) and what is usually called double carbide in the form of small rounded grains. When quenched from 1200°C. and given the first hardening treatment, the structure consists of austenite, (generally with some martensite) and also double carbide, also in the form of rounded grains. These so-called double carbides are undoubtedly complex in composition and we have but little knowledge of their constitution. After the secondary hardening the structure consists essentially of martensite and troostite, also with small rounded carbide grains. It is clear, therefore, that whether in the annealed or either of the hardened conditions the steels contain free carbide. In the usual language of metallography they are what is called hypereutectoid.

Twenty-two years ago I showed (¹) that a high-speed cutting tool containing carbon 0.77%, chromium 3.70%, tungsten 10.83%, when cooled either from about 900°C., 1000°C., or 1100°C., gave a normal γ to α plus carbide change point at about 730°C., whereas when the same steel was cooled from 1230°C., not only was this inversion completely absent but no inversion was observable on cooling until about 150°C. It was clear from this, that provided the tool was not heated above 1100°C., a carbide, probably a double carbide of iron and chromium, was formed and precipitated at about 730°C., but that this did not take place if the steel was heated as high as 1230°C. It is to be noted that this last-named temperature is that used in the hardening of high-speed cutting tools. It follows, therefore, that the heating of the steel to this temperature was sufficient to suppress the formation of the ordinary carbide and a natural inference would be that it was due mainly to the action of tungsten, since chromium has been shown not to produce this effect. Professor Edwards (²) after working on this subject some years later stated that at temperatures in the neighbourhood of 1200°C. a carbide was formed containing tungsten.

The sensitiveness of modern cutting tools to heat treatment is well shown in the accompanying figure. (Fig. 23.) The top curve shows the contraction at the α to γ change point on heating. This occurs at about 820°C. to 850°C. If the steel is then cooled the converse change, i.e., γ to α takes place with expansion at from 750°C. to 700°C. If the steel is heated to 925°C. and then cooled the expansion is lowered to about 420° to 380°C. If it is heated to

¹ Journ. Iron and Steel Inst., 1905, No. 1, plate 47.

² Journ. Iron and Steel Inst., 1908.

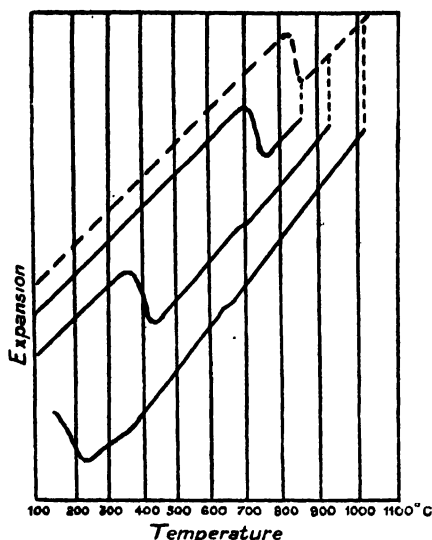


FIG. 23. Dilatation of High Speed Steel (de Nolly).

1025°C. and then cooled, the γ to α change is lowered to about 200°C. Although no curve was taken from a higher temperature there is no doubt that if the steel had been heated to and cooled from 1200°C. the γ to α change would have been lowered still further, possibly to below the ordinary temperature. At any rate, the results agree in showing that if these steels are heated only just above the main carbide change point and then cooled they invert normally at about 700°C., but that if they are heated to higher temperatures the change point is lowered discontinuously as has been previously shown in connection with tungsten and nickel steels.

It is now necessary to consider as carefully as possible the physical and physico-chemical changes which occur from the time the ingot is cast until the finished tool is produced. Only in this way is it possible to gain an insight into the structural changes which occur in the various heat treatments producing the final structure. Our knowledge of this subject to-day rests upon the work of many investigators and limits of space and time compel me to deal with this subject only in a condensed fashion. I wish, however, to mention the recent suggestive paper by Grossman and Bain entitled "On the Nature of High-Speed Steel."⁽¹⁾

High-speed steel solidifies very much after the manner of a white cast iron containing about 2% of carbon, in which cementite, Fe_3C is replaced by a complex carbide. Its structure is remarkably similar. It consists of primary grains of austenite (gamma iron), cored and more or less decomposed, together with the eutectic of austenite and carbide. The crystal grains are of two

¹ Journ. Iron and Steel Inst., 1924, No. II, pp. 249-272.

kinds (1) columnar, where they have been in contact with the mould and (2) cellular, where they have formed in the interior of the liquid. One of the most important points to be borne in mind is that there is a large concentration gradient from the centre to the periphery of the austenite grains. This produces a type of structure which plays a most important part in the subsequent treatment of the ingot and indeed is probably the cause of most of the manufacturing defects encountered. It is probable that the gradation of composition persists tenaciously and is by no means obliterated in the finished bar of steel. The rate of solution and diffusion of the coarse particles of carbide is very slow indeed, and the ordinary heating and manufacturing operations help comparatively little in securing uniformity of composition. The complexity of the steel containing as it does tungsten, chromium and vanadium, to say nothing of other elements in addition to iron and carbon, militates against an equalisation of composition by the ordinary methods of heat treatment. In the unannealed ingot the usual amount of eutectic found is about 13%.

In manufacturing practice the ingot may be annealed before heating for forging, or it may be taken directly from the casting operation while still hot, to be forged. In the case of annealing the ingot is heated up for a period of from 6 to 8 hours to a temperature of about 850°C., held at this temperature for a short time and then slowly cooled. Grossman and Bain⁽¹⁾ have shown that before annealing the ingot consists of primary grains (composed of two structures) and eutectic regions. The two structures are austenite (near the grain boundaries and eutectic regions) and sorbite. The sorbite of course represents austenite which has undergone the γ to α and carbide change. The effect of annealing is to change the whole of the austenite to spheroidised pearlite and sorbite and to cause some solution of the patches of carbide in the eutectic. On cooling the dissolved carbide is reprecipitated—this time in the form of very fine globules. The effect of this treatment therefore is to alter the form of some of the eutectic carbide. The microstructure at this stage is shown in Fig. 25.

When the ingot is forged the original grains are considerably deformed and refined but an even more important result is the crumbling of the carbide particles under the influence of work. These disintegrate with comparative ease and are flattened out by the work into what are known as carbide streaks. Some solution of the carbide also takes place during this operation and when the steel is subsequently cooled, precipitation takes place, again in the form of much finer particles. Forging has a beneficial effect in breaking up and refining the structure of the ingot, rendering it somewhat more homogeneous and refining the size of the carbide particles. It is doubtful whether much equalisation of composition by diffusion takes place. The important effect is largely due to the mechanical kneading. The cores are "churned" out gradually and the eutectic regions fragmentised.



FIG. 24. Broken Tips. $\times 10$.

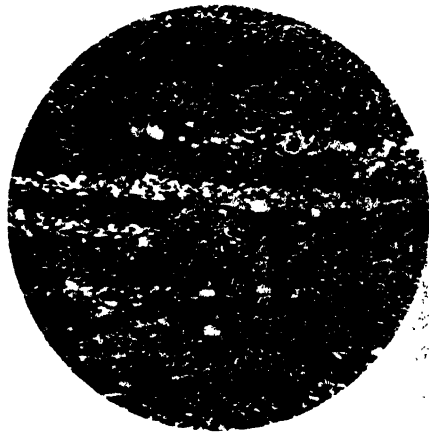


FIG 25 Annealed Steel $\times 500$

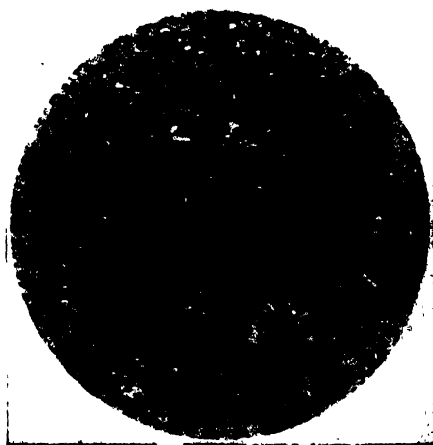


FIG. 26. Hardened Tool. $\times 500$.

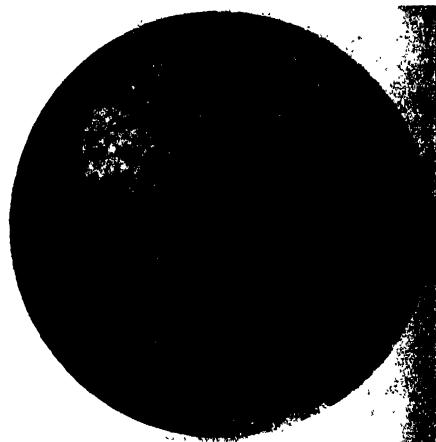


FIG. 27 Used Edge. $\times 500$

Structures of High Speed Cutting Tools.

Grossman and Bain have attempted to obtain some definite data on the question as to the extent to which the various alloy elements present in high-speed steel enter into the reactions involved in heat treatment. The steel upon which they experimented had the following compositions :—

Carbon	...	...	...	...	0.70 per cent.
Tungsten	...	...	...	...	18.50 " "
Chromium	...	...	...	...	4.17 " "
Vanadium	...	...	...	...	1.11 " "

Test specimens were heated at a variety of temperatures ranging from 926°C. to 1310°C. and then quenched in oil. From each group one specimen was kept as quenched and one was reheated to each of the following temperatures: 150°, 260°, 390°, 482°, 593°, 648°, and 705°C. The specimens were then subjected to an electrolytic solution process which had for its object the solution of the iron (together with any alloy elements present) and the retention of any carbides present in the form of a residue. The carbides were analysed for the total of carbon, tungsten, chromium and vanadium. From their results the authors estimated the composition of the carbide in the annealed steel, and the changes in composition which occurred on quenching and heating at various temperatures. The method is not sufficiently accurate to enable any well established conclusions to be drawn from it, but the authors conclude that in the annealed steel the whole of the tungsten and vanadium and about half the chromium is present in the form of carbide, i.e., a complex carbide with iron, while the remaining half of the chromium is dissolved in the remainder of the iron. From this they draw the further conclusion that annealed high-speed steel consists of about 70% by weight of a solid solution of chromium in iron and 30% of complex carbide. The composition of the carbide is considered to be :—

Carbon	...	...	...	...	2.3 per cent.
Chromium	...	...	...	...	6.3 " "
Tungsten	...	...	...	...	61.0 " "
Vanadium	...	...	...	...	3.6 " "
Iron (by difference)	...	...	...	...	26.8 " "

It will be seen that more than three-fifths by weight of the carbide consists of tungsten.

Of the maximum 30% carbide content, the most dissolved in any quench was about 13%. Grossman and Bain conclude that of the alloying elements chromium is the most soluble on heating to high temperatures. This is followed by tungsten and lastly by vanadium which showed the least tendency to dissolve.

Accepting for the time being the broad conclusions of Grossman and Bain as described above it is now possible to consider the mechanism of the hardening of a piece of finished high-speed tool steel. This material may be regarded according to this view, as essentially a binary alloy, one constituent of which is a solid solution of chromium in α iron and the other the complex carbide. The finished worked bar contains on an average 30% of carbide by weight, but this is not equally distributed. Rather more than half of it is in the form of fine particles which have been precipitated from solid solution after the metal solidified. On account of "coring" in the original dendrites which is never completely removed a concentration-gradient exists from the centres to the edges of these areas, which represent the original grains. The remainder of

the carbide is present in comparatively coarse particles which represent the plates of carbide in the original eutectic. These are still present in pronounced streaks throughout the piece.

Consider this aggregate to be heated to the usual quenching temperature for high-speed steel (from 1200° to $1250^{\circ}\text{C}.$) Rather above $850^{\circ}\text{C}.$ the α iron begins to invert to γ iron. As the temperature is raised the complex carbide begins to dissolve in it. Its solubility increases so that at the highest temperature probably nearly half the total carbide has been dissolved in the matrix. It is only at the highest temperatures that tungsten dissolves (see cooling curves). In spite of this degree of solution, however, the austenite formed is far from homogeneous on account of the retarding influence on diffusion of the alloying elements and probably in particular of the very heavy metal tungsten. It is important to emphasise this heterogeneity of the austenite formed under the ordinary conditions of heat treatment of the tools. Moreover the fortuitous distribution of the large carbide particles present in the original eutectic is another cause of the existence of concentration gradients, which militate against the production of homogeneous austenite. Probably these particles of excess carbide exercise a very useful influence in preventing grain growth at the high temperatures used in heat treatment. But for their obstructing action it would certainly be rapid and the properties of the resulting steel would be inferior. This indeed is probably the main reason why the presence of excess carbide particles in the steel is beneficial.

When the steel has been heated for sufficient time at a high temperature it is quenched. In this process a mixture of austenite and martensite is formed so that a section of the freshly quenched high-speed steel shows microscopic grains consisting of a mixture of austenite and martensite and distributed through them the excess carbide particles which remain dissolved at the quenching temperature. Light etching (Fig. 26) reveals only the austenite grains and carbide particles but deeper etching develops the martensite structure. The relative proportions of martensite and austenite vary from place to place and follow variations in the concentration of the carbide. The grains richer in carbide particles are mainly austenite while those poorer in carbide are mainly martensitic. A piece of freshly quenched high-speed tool steel may thus be considered as containing regions of an austenite-martensite mixture of varying stability.

These differences in stability become noticeable when the steel is given the second heat treatment at about $600^{\circ}\text{C}.$ required to produce secondary hardness. We have to consider what happens both to the austenite and martensite. So far as the austenite is concerned this is transformed to a very great extent to martensite and perhaps even to some slight extent distributed through the steel although those areas with a lower concentration of carbon transform much more readily and therefore at a slightly lower temperature than do the richer

areas. The martensite for its part also tends to decompose and passes to some extent into troostite and sorbite. Each of these changes has an effect upon the hardness of the tool. The austenite to martensite transformation is accompanied by a great increase in hardness while the martensite to troostite and sorbite transformation is accompanied by softening. Inasmuch as considerably more austenite is transformed into martensite, than martensite is to troostite and sorbite, the effect of this change on balance is to harden the steel and *this is the cause of secondary hardening*. It is now clear why the tool as quenched is not as hard as the tool after the secondary hardening, viz., because it contains considerably more austenite than martensite.

It remains to consider the cause of red hardness, i.e., the retention of the secondary hardness of the tool at a red heat. Here we are in the region of surmise. We have after secondary hardening a matrix composed mainly of martensite but containing in addition some troostite and sorbite and carbide particles. The fact that a high-speed cutting tool exhibits red hardness means that this structure is stable. It is not stable in a plain carbon steel. It is only slightly less unstable in a Mushet steel. Why then is it stable in a high-speed steel? My own view is that the complex carbide particles containing tungsten, chromium and vanadium stabilise, and these support the martensite structure up to about 620°C. It is certain that if the carbide particles could migrate through the martensite so as to coalesce and form large spheroids of carbide red hardness would be lost. In steels with low alloy content this is what happens. The high-speed cutting tool represents an alloy or rather a range of alloys in which this structural stability is secured.

We are now in a position to say how far we can explain the facts stated at the beginning of this section and designated as the special characteristics of high-speed cutting tools. (1) The very high temperature required in the hardening treatment of these steels is necessary, because it is only in this way that the solution of the alloying elements and particularly of tungsten can be brought about and the formation of the hard carbides ensued. (2) After the original quenching the steels are not in the hardest condition because they contain a considerable amount of austenite which is not a hard constituent. (3) The cause of the secondary hardness produced by the second heat treatment at 575-620°C. is the transformation of austenite to martensite (which is hard). Some softening also takes place due to the transformation of some of the martensite to troostite and sorbite, but on balance the steel is much harder. (4) The cause of red hardness cannot be stated with the same degree of certainty. It seems probable that it is due to the structural stability conferred on the martensite by the presence of heavy immobile particles of complex carbides containing tungsten and chromium (and in many cases vanadium). The microstructure of a used edge, where the austenite-martensite structure has been tempered to sorbite structure is shown in Fig. 27.

HEAT-RESISTING STEELS.

Many of the requirements of modern engineering demand the use of metals and alloys which are capable of service above the atmospheric temperature. Two main aspects of this have to be considered (1) The variation in properties with rise of temperature and (2) the resistance of the metal to the atmosphere in which it is heated. Metals and alloys are needed which can stand up to their work at temperatures up to 1000°C . The atmospheres concerned may consist of air, steam, carbon dioxide, sulphur dioxide and, speaking generally, of furnace gases which may vary considerably in composition. It is not proposed to say anything about the variation in mechanical properties of metals with change of temperatures. This is far too big a subject to treat at this stage. It is a difficult problem to investigate and, in spite of its great importance, has hardly yet been tackled sufficiently seriously. There is no doubt, however, that it will have to be tackled, and that in the solution of the problems involved alloy steels will play a most important part.

A few words, however, may be said about the second aspect of the problem, viz., the resistance of metals and alloys to atmospheres at different temperatures. All alloys of iron are attacked more or less under the conditions mentioned. The attack on iron itself and on plain carbon steels, particularly at temperatures above 600°C ., is both rapid and extensive, and it becomes therefore of great practical importance to discover alloys whose resistance to corroding influence under these conditions would be very much less. Dr. W. H. Hatfield has recently published some valuable data on this question¹. He has subjected fifteen steel alloys to temperatures of from 700° to 1000°C . in (1) oxygen, (2) steam, (3) carbon dioxide, and (4) sulphur dioxide. The duration of exposure was 24 hours. This is somewhat short if an alloy is being tested for its resistance to a particular atmosphere, and it is to be hoped that he will extend his tests to periods of greater duration. Short though the times of these tests were, they have given decidedly interesting results, and Tables 21, 22, 23 and 24 show the results obtained in the four atmospheres mentioned.

Attention may be drawn to the fact that 9 out of 15 steels contained chromium. This suggests that it was anticipated by the author that chromium would be found to be particularly valuable in conferring resistance to hot corroding gases. Such has in fact proved to be the case. In judging the degree of resistance exhibited it should be pointed out that the lower the index figure the more resistant is the steel.

The attack on the mild steel was severe in all the gaseous media and particularly in sulphur dioxide where the metal was completely destroyed. The 3% nickel steel was still worse in oxygen and carbon dioxide, equally bad in sulphur dioxide, and rather better in steam. 36% nickel steel was much more resistant in oxygen, steam and carbon dioxide, but was severely attacked by sulphur

¹ "Heating Resisting Steels," Journ. Iron and Steel Inst., May, 1927.

TABLE XXI.

THE EFFECT OF OXYGEN ON STEELS AND OTHER ALLOYS AT VARIOUS HIGH TEMPERATURES.

Symbol.	Material.	Index Figure.			
		700°C.	800°C.	900°C.	1000°C.
G	Mild Carbon Steel	10.422	29.760	83.411	170.860
H	3% Nickel Steel	40.032	51.240	67.025	230.286
I	36% Nickel Steel	4.122	9.727	14.039	25.548
J	Silicon-chromium Steel ..	0.260	1.668	2.07	2.94
K	Chromium Steel	0.223	1.904	2.789	91.30
L	Chromium Steel	0.600	0.739	1.895	2.886
M	Chromium-nickel Steel ..	0.64	1.138	4.080	43.577
N	Chromium-nickel Steel ..	1.079	1.047	2.707	5.659
O	Nickel-chromium Steel ..	1.736	7.285	11.667	19.305
P	Chromium-nickel-silicon steel	0.168	0.339	1.262	1.806
Q	Chromium-nickel-tungsten Steel	0.033	0.050	0.202	3.489
R	Nichrome	0.243	0.491	0.764	1.778
S	Cast Iron	11.773	56.767	129.113	427.546
T	15% Silicon Iron	1.447	3.932	4.354	78.651
U	Monel Metal	1.728	—	108.602	—

TABLE XXII.

THE EFFECT OF STEAM ON STEELS AND OTHER ALLOYS AT VARIOUS HIGH TEMPERATURES.

Symbol.	Material	Index Figure.			
		700°C.	800°C.	900°C.	1000°C.
G	Mild Carbon Steel	3.657	21.970	74.932	231.051
H	3% Nickel Steel	8.693	35.862	46.113	91.914
I	36% Nickel Steel	3.159	13.381	36.202	54.541
J	Silicon-chromium Steel ..	0.344	0.535	0.946	1.355
K	Chromium Steel	0.520	0.573	14.913	39.841
L	Chromium Steel	0.235	0.583	2.031	3.260
M	Chromium-nickel Steel ..	0.465	1.876	19.944	43.439
N	Chromium-nickel Steel ..	0.24	0.50	6.14	17.456
O	Nickel-chromium Steel ..	1.305	2.044	6.153	16.027
P	Chromium-nickel-silicon steel	0.100	0.266	0.926	1.496
Q	Chromium-nickel-tungsten Steel	0.098	0.305	0.370	2.765
R	Nichrome	0.227	0.303	1.410	1.434
S	Cast Iron	22.615	46.493	94.093	238.353
T	15% Silicon Iron	2.20	92.976	210.487	418.304
U	Monel Metal	0.636	—	18.927	—

TABLE XXIII.
THE EFFECT OF CARBON DIOXIDE ON STEELS AND OTHER ALLOYS AT VARIOUS TEMPERATURES.

Symbol.	Material.	Index Figure.			
		700°C.	800°C.	900°C.	1000°C.
G	Mild Carbon Steel	10.025	36.738	74.916	93.460
H	3% Nickel Steel	9.845	29.155	50.818	151.339
I	36% Nickel Steel	2.783	9.995	25.395	30.734
J	Silicon-chromium Steel	0.245	0.213	0.426	0.841
K	Chromium Steel	0.810	0.870	16.045	62.283
L	Chromium Steel	0.235	0.757	2.889	2.948
M	Chromium-nickel Steel	1.427	2.094	12.408	37.008
N	Chromium-nickel Steel	0.301	1.080	3.254	5.85
O	Nickel-chromium Steel	1.054	2.205	7.328	11.654
P	Chromium-nickel-silicon Steel	0.122	0.224	0.550	0.584
Q	Chromium-nickel-tungsten Steel	0.148	0.148	0.317	0.922
R	Nichrome	0.411	0.438	0.548	1.134
S	Cast Iron	13.953	18.547	21.133	40.568*
T	15% Silicon Iron	173.941†	1.523	5.814	29.473
U	Monel Metal	2.60	—	21.203	—

* Thin film, dark grey adherent.

† Abnormal local expansion resulting from "growth."

TABLE XXIV.
THE EFFECT OF SULPHUR DIOXIDE ON STEELS AND OTHER ALLOYS AT VARIOUS HIGH TEMPERATURES.

Symbol.	Material.	Index Figure.			
		700°C.	800°C.	900°C.	1000°C.
G	Mild Carbon Steel	9.857	41.641	177.007	Converted
H	3% Nickel Steel	30.192	450.675	700.13	Converted
I	36% Nickel Steel	20.120	141.315	199.112	256.447
J	Silicon-chromium Steel	0.52	1.275	4.550	3.235
K	Chromium Steel	0.398	1.041	9.933	58.616
L	Chromium Steel	0.453	0.545	0.823	1.433
M	Chromium-nickel Steel	1.055	1.16	1.720	3.748
N	Chromium-nickel Steel	1.432	1.648	1.833	2.633
O	Nickel-chromium Steel	0.293	0.414	0.417	7.939
P	Chromium-nickel-silicon Steel	0.380	0.600	1.149	2.412
Q	Chromium-nickel-tungsten Steel	0.204	0.399	0.539	0.829
R	Nichrome	0.33	5.044	55.624	91.104
S	Cast Iron	6.757	33.973	85.360	Converted
T	15% Silicon Iron	1.402	1.920	4.867	160.396
U	Monel Metal	43.904	—	Converted	—

dioxide. The silicon-chromium steel stood up extremely well under all tests. The behaviour of chromium steels shows that chromium confers a substantial increase in resistance, though neither of the alloys was as resistant as the silicon-chromium steel. The steels containing chromium and nickel in different proportions behaved somewhat variably. Two of the most resistant steels in the series were a chromium-nickel-silicon and a chromium-nickel-tungsten. These stood up best on the whole to attack by hot gases. Nichrome was resistant in all cases except sulphur dioxide. Cast iron was heavily attacked in all cases. Chromel metal proved to be one of the least resistant of the alloys tested.

From these results, which it must be emphasised cannot be regarded as other than preliminary, it would seem that the resistance conferred by chromium to steel at the ordinary temperatures which finds application in the manufacture of stainless steels, is also shared by the metal at high temperatures. Certain compositions in the silicon-chromium, chromium-nickel, chromium-nickel-silicon, and chromium-nickel-tungsten alloys look decidedly promising, and their behaviour under test justifies a much more prolonged trial than any to which they have yet been subjected.

Figures 3 and 7 illustrating the microstructures of steels were kindly prepared for me by Mr. W. H. Dearden.

Figures 21 and 22 are reproduced with the kind permission of the Iron and Steel Institute from Journal No. II, 1926, Vol. CXIV.

The photographs from which Figures 24 and 27 are reproduced I owe to the kindness of Dr. W. H. Hatfield.

CORRESPONDENCE.

INDIAN TARIFF BOARD.

Mr. Arnold Lupton raises a pertinent question in the *Journal* of February 3rd, and I, as chairman of the meeting, can assure him that he would have received an attentive hearing had he been present and raised the point he mentions. The point is, however, more directly concerned with the policy of discriminating protection adopted by India than with the actual working of the Tariff Board, but I think the whole tenor of Sir David Chadwick's address went to show how careful has been the Tariff Board, in its efforts to foster sound industry, to place no avoidable burden on the people.

The Fiscal Commission frankly explored the cost to India of the policy it advocated, a temporary burden for the sake of a permanent gain (*vide* chap. V of its Report), and was much criticised for hedging its recommendations round with precautions in order to protect the interests of the consumer.

Mr. Lupton mentions tariffs on iron and cotton. The tariff on steel, which is now on the downgrade, has saved an industry which gives employment to thousands and which, there is reason to hope, will, at no distant date, be able to stand alone. It is doubtful whether the extra cost of steel rails has even indirectly increased

the cost of travelling in a country where that cost is the lowest in the world. But I must remind Mr. Lupton that travelling in India, except in the case of those who directly benefit by the industrial betterment of the country, is largely a luxury. In the case of the steel industry I think it may safely be hazarded that the permanent gain to the country will far outweigh the temporary loss.

In regard to cotton goods, the Tariff Board refused direct protection. The indirect protection sanctioned can have little effect compared with the revenue duties, which existed long before the Tariff Board came into being. In so far as those revenue duties encourage the hand-loom industry, there is a resulting gain to large numbers of the poorer classes, scattered all over the country, and many Indians believe that the hand-loom industry should be fostered for reasons that are not purely economic.

The poverty of the peasantry in India is a regrettable fact, but the causes of that poverty lie much deeper than can be discussed in this connection. I have seen no evidence that this poverty has been intensified by reason of the action of the Tariff Board up to the present time. An informed public opinion and adequate representation of agricultural interests in the councils are the natural safeguards against the evils Mr. Lupton fears. The publicity given to the enquiries and findings of the Tariff Board have had a marked educative effect during the past few years, as will be seen by a comparison between the Assembly debates before and since the Board entered on its labours.

CAMPBELL RHODES.

NOTES ON BOOKS.

CHEMICAL AFFINITY. By L. J. Hudleston, M.C., B.Sc., A.I.C., Lecturer in Physical and Inorganic Chemistry at the University College of Wales, Aberystwyth. London: Longmans, Green & Co., Ltd. 7s. 6d. net.

If asked to name the more important advances in knowledge which have been made during the last twenty years in the borderland common to physics and chemistry, the well-informed layman might have no difficulty in remembering such spectacular examples as those furnished by atomic structure and crystal structure; but the subject of chemical thermodynamics would hardly be included in this list. Nevertheless, it is scarcely inferior in importance or ultimate value, though the lines on which it has to be treated are so mathematical and abstract that it can never hope to attract popular interest.

In the purely chemical branch of the much wider subject of thermodynamics the problem of affinity (or tendency to chemical reaction) occupies a central position. The inquirer, however, would be disappointed if he hoped to receive from this source very much light on the *nature* of chemical forces: what is discussed thermodynamically is the *magnitude* of the affinity, and especially the manner in which this magnitude varies with the conditions.

The foundations of the modern treatment of affinity were securely laid by Van't Hoff and Nernst in Europe and by Willard Gibbs in America; but the subject has been greatly enlarged and transformed in more recent years by the work of another American, G. N. Lewis. The latter has himself made the new conceptions available in text-book form, but in so difficult a subject no one will be above feeling gratitude for a little extra assistance, and Mr. Hudleston's essay in elucidation will receive a warm welcome from students of physical chemistry.

In form it is more explanatory than Lewis and Randall's "Thermodynamics," and, although the argument is on occasion inevitably a little difficult to follow at a first reading, Mr. Hudleston is to be congratulated on his power of foreseeing difficulties and misconceptions, and of forestalling them by ingeniously chosen and neatly worded little propositions.

No student could read the first chapter, entitled "Energy and its Transformations," without experiencing a pleasant enlargement of horizons, achieved at the cost of very moderate mental effort; and the same applies in a modified degree to the two following chapters on Entropy and Free Energy. The main pith of the book, considered as an exposition of recent progress, is perhaps to be found in the chapter on Solutions, after which attention is paid to another aspect of the subject, namely, the "new" Heat Theorem of Nernst. Finally, the value of the book is greatly increased by a chapter of numerical applications of the principles previously developed.

There are to be noted a few cases in which the sense would have been made more immediately obvious by the insertion of an extra comma, and the repeated misuse of the word "postulate" becomes irritating, though it appears to be growing common. On page 54 there appears an unusual notation for partial differential coefficients, which may possibly be a misprint, and which would certainly be a little distracting if it occurred very often; but on this same occasion Mr. Hudleston affords a good instance of his real kindness and sympathy towards students, in referring them to an excellent account of the mathematics of partial differentiation, in case their appreciation of the various aspects of this process should be in need of strengthening. One is glad to escape temporarily from the cacophonous American forms "molal" and "molality" to the English "molar," even though one realises that the adjective *molaris* does not appertain to the noun *moles*.

THE ACOUSTICS OF BUILDINGS. By A. H. Davis and G. W. C. Kaye. London: G. Bell and Sons, Ltd. 15s. net.

Probably the best known book on Architectural Acoustics is W. C. Sabine's "Collected Papers," but, as its title indicates, it is a collection of papers which were not originally intended to form a book and, valuable as the papers are, they lack cohesion and continuity when considered as a general treatise. Unfortunately, the author's premature death prevented revision. Other writers, like Rayleigh, Jaeger and Watson, have been primarily concerned with their own theories and experiments. Consequently, *The Acoustics of Buildings* is a most welcome addition to the present writings on this subject, and will prove of the utmost value alike to the architect who requires some sound fundamental principles to guide him in a general way and to the physicist wishing to delve deeper into the purely theoretical side of the subject.

The joint authors have collected the main facts and theories of many other writers and have presented these in such a way as to be readily understandable by the lay mind. They have further shown how their own theories, experiments and results confirm and strengthen principles which may now be regarded as fundamental. The sound-pulse and ripple-tank method in Chapter III dealing with "the study of the shape of an auditorium" must prove of great interest to those architects who are entrusted with the design of large auditoria and in this direction it is to be hoped that the promise of further investigations to produce means for securing "three dimension study" will soon be forthcoming.

In those chapters dealing with transmission of sound one could have wished that

the experiments quoted had been of a more practical kind and conducted on specimens of a size usually employed in building practice ; also tests of commercial sound deadeners are of little value unless they are made on the materials as they would ordinarily be used. The behaviour of a material rigidly fixed at the edges over an aperture of only 5ft. by 4ft. may very well give a misleading impression as to the results to be expected when the same material is used in actual building construction. The authors certainly draw attention to the necessity for tests on full size specimens but, unfortunately, they are not forthcoming. Perhaps, with the present groundwork to build upon, we may look forward to the publication in the near future of data on the transmission of sound which will be of the same practical value to the architect and builder as is the other information in the book.

LIFE AND WORK OF THE PEOPLE OF ENGLAND. FIFTEENTH CENTURY. By D. Hartley and M. Elliot. London : B. T. Batsford, Ltd. 4s. 6d.

This book belongs to a valuable series. It is intended to be read in schools, and the introduction and notes are written in a friendly and comprehensible style. But let it not be supposed that the information contained here is beneath the notice of grown-ups, even though the occasionally disingenuous comments invite criticism. Is it hard "to understand the people's enjoyment of bear-baiting and cock-fighting?"

A pleasanter subject is fifteenth century cuisine. A recipe for sausage rolls is : "Take breadcrumbs and eggs, and swing them together with ham, add sage, safron and salt, wrap it up in a cloth and cast it into boiling broth." Theatrical producers were not in the direct line of ancestry of Mr. Craig. A realistic paradise on the stage had : "A windlass and ten wheels hung with lanthorns, and angels tied on strong ropes with a counterpoise of lead under their feet." The English character was already enigmatic to foreigners. The Venetian ambassador is quoted as writing : "I have never noticed anyone, either at court or among the lower orders, to be in love ; whence one must necessarily conclude, either that the English are the most discreet lovers in the world or that they are incapable of love." The English are still the most undemonstrative people among the white races.

The culture of the fifteenth century is for many reasons deserving of more study than is given it. For the sixteenth century did not blossom into full glory unaccountably ; the generations preceding the great Elizabethans naturally prepared the way for them. All-roundness was becoming an English ideal ; which it succeeded in remaining till a few years ago. Raleigh was the typical figure of the later period ; poet, soldier, explorer. Influences of the Italian renaissance brought out the sensibilities of the English people, who were hearty and full of vitality and more artistically inclined than the crowds of to-day. Their individualities were built up round the relevant facts of life.

Any book is welcome which dispels the illusion under which many children are made to labour by bad teaching, the illusion that the middle ages were not crowded with life and activity. It is obvious that pictures are a good medium for conveying the truth about this, in spite of a sense of unreality which never quite ceases to cling to the old-fashioned styles of representation. But the authoresses of the present series have done their best to bridge the gap with their captions, which are often admirably suggestive of those human moods which do not change with the ages.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, FEBRUARY 20. Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Professor Dr. A. P. Laurie, "Stone Preservation and Decay." Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m. Geographical Society, at 135, New Bond Street, W. 8.30 p.m. Mr. George Watkins, "The Cambridge Expedition to Edge Island." Mechanical Engineers, Institution of, Storey's Gate, S.W. 6.30 p.m. Informal Discussion on "The Relative Importance of Sales, Design and Works Organization in Engineering." Victoria Institute, at the Central Hall, Westminster, S.W. 4.30 p.m. Prof. Dr. Theophilus Pinches, "The Influence of Mythology and Heathen Practices of the Canaanites upon the Hebrews." University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Prince D.S. Mirsky, "The Russian Novel after 1880." (Lecture VI.) At King's College, Strand, W.C. 5.30 p.m. The Rev. C. F. Rogers, "Ecclesiastical Music." (Lecture II.) At University College, Gower Street, W.C. 2 p.m. Prof. Dr. L. M. Brandlin, "The French Chansons de Geste." 5 p.m. Dr. A. S. Parkes, "The Internal Secretions of the Gonads." (Lecture IV.) 5.30 p.m. Dr. E. A. Baker, "George Meredith." (Lecture II.)

TUESDAY, FEBRUARY 21. Automobile Engineers, Institution of, at the Engineering and Scientific Club Wolverhampton. 7.30 p.m. Mr. C. R. F. Engelbach, "Works Re-organisation to Increase Production." Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. Charles E. Keyser, "A Comparison of the Norman Doorways of Yorkshire, Norfolk and Gloucestershire." Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Prof. J. S. Huxley, "The Behaviour of Animals." Statistical Society, at the Royal Society of Arts, Adelphi, W.C. 5.15 p.m. Dr. T. H. C. Stevenson, "The Vital Statistics of Wealth and Poverty." Transport, Institute of, at the Institution of Electrical Engineers, Savoy Place, W.C. 5.45 p.m. Prof. J. F. Rees, "The Development of Transport Facilities in the Midlands during the first part of the 19th century." University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Sir Bernard Pares, "Russian History from Peter the Great to 1861." (Lecture V.) At King's College, Strand, W.C. 5 p.m. Dr. J. A. Hewitt, "Integration in the Nervous System." (Lecture VI.) 5.30 p.m. Prof. Dr. S. Alexander, "Emergence, or Primary, Secondary and Tertiary Qualities of Things." (Lecture III.) At University College, Gower Street, W.C. 8.15 p.m. Miss E. Jeffries Davis, "More London Place-Names." (Lecture III.) Zoological Society, Regent's Park, N.W. 5.30 p.m. Scientific Business Meeting.

WEDNESDAY, FEBRUARY 22. Geological Society, Burlington House, W. 5.30 p.m. Dr. C. A. Matley, "The Pre-Cambrian Complex and Associated Rocks of South-Western Llyn (Carnarvonshire)." L.C.C. The Geffrey Museum, Kingsland Road, E. 7.30 p.m. Mr. E. Hawking, "Chairs: History, Manufacture and Preservation." Public Health, Royal Institute of, 37 Russell Square, W.C. 4.30 p.m. Dr. J. E. Whitely MacFall, "Some Aspects of Legal Live Birth." University of London, at University College, Gower Street, W.C. 3 p.m. Signor Camillo Pellizzi, "La Lirica del Paradiso." (Lecture VI.) 4 p.m. Prof. A. V. Hill, "Muscle." (Lecture VI.) 5.30 p.m. Mr. I. C. Grondahl, "Norwegian Country Life, Customs and Sayings." (Lecture III.) 6 p.m. Prof. Dr. A. L. Bowley, "Measurement by Index Numbers—Theory and Application to recent Economic History." (Lecture IV.)

THURSDAY, FEBRUARY 23. British Empire Producers' Organisation, at the Royal Society of Arts, Adelphi, W.C. 4.30 p.m. Chadwick Lecture, at the British Medical Association, Tavistock Square, W.C. 5.15 p.m. Sir W. H. Hamer, "Epidemiology in England during the last Hundred Years—(Part II) The Return to the Hippocratic Method." Chemical Society, at Burlington House, W. 8 p.m. Prof. A. Fowler, F.R.S., "Spectra and Atoms." Royal Society, Burlington House, W. 4.30 p.m. Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Prof. F. Ll. Griffith, "Nubia in Antiquity and in the Middle Ages." University of London, at Bedford College for Women, Regent's Park, N.W. 5.15 p.m. Mr. W. J. Turner "Beethoven." At the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. V. Tchitchovskiy, "Social and Economic Conditions in Modern Bulgaria." (Lecture III.) At King's College, Strand, W.C. 5.30 p.m. Vice-Admiral Sir Richard Webb, "The Protection of Commerce in War." 5.30 p.m. Dr. F. W. Rogers Brambell, "The Development of Sex, with special reference to recent work on Birds and Amphibians." (Lecture VI.) At University College, Gower Street, W.C. 5 p.m. Dr. R. J. Ludford, "Cytology in Relation to Physiological Processes." (Lecture VI.) 5.15 p.m. Prof. J. E. G. de Montmorency, "Customary Law in the British Empire." (Lecture V.) 5.30 p.m. Prof. E. W. Tristram, "English Mediæval Painting." (Lecture I.) Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Prof. J. H. Worthington, "English Steps and Staircases."

FRIDAY, FEBRUARY 24. Engineering Inspection, Institution of, at the Royal Society of Arts, Adelphi, W.C. 7.30 p.m. Major R. Vernon C. Brook, "The Inspection of Public Service Vehicles." Mechanical Engineers, Institution of, Storey's Gate S.W. 7 p.m. Exhibition of Industrial Kinematograph Films. North East Coast Institution of Engineers' Shipbuilders, at the Mining Institute, Newcastle-on-Tyne. 6 p.m. Messrs. G. U. L. Sartoris and K. Watson, "The Michell Crankless Engine." Physical Society, at the Imperial College of Science and Technology, South Kensington, S.W. 5 p.m. 1 Mr. W. H. J. Childs, "Some Methods of Estimating the Intensities of Spectral Lines." 2 Professor P. W. Burbidge, and Mr. N. S. Alexander, "Electrical Methods of Hygrometry." 3 Mr. L. Hartshorn, "Constants of Thermionic Valves." Royal Institution, 21, Albemarle Street, W. 9 p.m. Prof. George Gordon, "The Lives of Authors." University of London, at Guy's Hospital Medical School, Borough, S.E. 5.30 p.m. Dr. Graham Simpson, "The Surgery of the Kidney and Ureter." (Lecture III.) At the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Mr. Julian Krzyzanowski, "Polish Literature." (Lecture V.) At King's College, Strand, W.C. 5.30 p.m. Dr. R. W. Seton-Watson, "The States of the Little Entente." (Lecture IV.) 5.30 p.m. Mr. Cyril J. Gadd, "Ur in the time of Abraham." 5.30 p.m. Mr. P. Alexander, "The Drama of Eale." At University College, Gower Street, W.C. 5 p.m. Mr. C. F. A. Pantin, "Comparative Physiology." (Lecture VII.) 5.30 p.m. Mr. S. G. Tallents, "The Work of the Empire Marketing Board."

SATURDAY, FEBRUARY 25. L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Miss M. Edith Durham, "Primitive Life in South-East Europe." Royal Institution, 21, Albemarle Street, W. 3 p.m. Mr. Campbell Dodgson, "The Life and Work of Albrecht Dürer."

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FRIDAY, FEBRUARY 24th, 1928.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK

MONDAY, FEBRUARY 27th, at 8 p.m. (Cantor Lecture.) HERBERT JOHN GOUGH, M.B.E., B.Sc., Ph.D., Engineering Department, National Physical Laboratory, "Fatigue Phenomena, with special reference to Single Crystals." (Lecture III.)

TUESDAY, FEBRUARY 28th, at 4.30 p.m. (Dominions and Colonies Section.) SIR STEPHEN MONTAGU BURROWS, C.I.E. (late Ceylon Civil Service), "The Ancient Civilisation of Ceylon." EDWARD BRUCE ALEXANDER, Esq., C.M.G., will preside.

Tea will be served in the library from 4 p.m.

WEDNESDAY, FEBRUARY 29th, at 8 p.m. (Ordinary Meeting.) ARCHIBALD CRAWFORD, ESQ., K.C., Director of the Economic League, "Industry Fifty Years Hence." THE RIGHT HON. G. N. BARNES, P.C., C.H., Member of the Council of the Society, will preside.

COUNCIL.

A meeting of the Council was held on Monday, February 13th. Present:—Sir Philip Magnus, Bt., in the Chair; Sir Charles H. Armstrong; Lord Askwith, K.C.B., K.C., D.C.L.; Mr. Llewelyn B. Atkinson, M.I.E.E.; Sir Charles Stuart Bayley, G.C.I.E., K.C.S.I.; Sir William Henry Davison, K.B.E., D.L., M.P.; Mr. Peter MacIntyre Evans, M.A., LL.D.; Sir Arthur Holbrook, K.B.E., M.P.; Major Sir Humphrey Leggett, R.E., D.S.O.; Col. The Master of Sempill; Mr. Alan A. Campbell Swinton, F.R.S.; Mr. Carmichael Thomas; and Lt.-Col. Sir A. T. Wilson, K.C.I.E., C.S.I., C.M.G., D.S.O., with Mr. G. K. Menzies, M.A. (Secretary) and Mr. W. Perry, B.A. (Assistant Secretary).

The thanks of the Council were accorded to Mr. James H. Hyde for his generous donation of £500 to the Society's Fund for the Preservation of Ancient

Cottages. Mr. Hyde had previously contributed 500 guineas to the Fund.

It was reported that the installation of the Ross Cinematograph Projector, of which half the cost had generously been contributed by Sir Charles Parsons, had been completed.

Further consideration was given to the question of the award of the Society's Albert Medal for 1928.

In view of the immediate demand for copies of Dr. A. E. Dunstan's Cantor Lectures on "The Scientific Foundation of the Refining of Petroleum," special arrangements were made for their publication.

The following candidates were duly elected Fellows of the Society:—

Bartholomew, Mrs. Annie May, London.

Chamberlin, Charles Grover, Ph.B., Brooklyn, New York, U.S.A.

Chambers, Alfred Eustace, Assoc. M.Inst.C.E., London.

Cherry, Edward J., St. Margaret's-on-Thames, Middlesex.

Dent, Major Herbert Crowley, M.B.E., Cromer.

Fiumi, Cav. Napoleoni Giovanni, Milan, Italy.

Fort, Michel, Lima, Peru, South America.

Ginner, Charles, London.

Hanbury, Reginald Janson, M.R.C.S., L.R.C.P., Woldingham, Surrey.

Holden, Arthur Stanley, London.

Hughes, Frank George, Southsea, Hants.

Hunt, Lieutenant George, R.N. (retired), London.

Macdonald, Mrs. Lucy W., London.

Munford, Cyril James, London.

Pears, Harry Septimus, Worthing.

Pereira, Armando de Arruda, Sao Paula, Brazil, South America.

Qadri, Syed Gulam Mohuiddin, M.A., London.

Russell, Miss Naomi, London.

Simon, Trevor B., Fairmont, W. Virginia, U.S.A.

Soames, Reginald, London.

Thacker, D. D., Jharia, Bihar and Orissa, India.

Walker, William, A.R.E., Callander, Perthshire.

Warren, George C., Boston, Mass., U.S.A.

The arrangements for the final part of the session were further considered. Other formal and financial business was transacted.

TWELFTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 15th, 1928. COMMODORE SIR RICHARD WILLIAMS-BULKELEY, Bt., K.C.B., R.N.R. (Commodore, Royal Yacht Squadron) in the Chair.

A paper on "Trinity House: its History and its Work" was read by CAPTAIN SIR ARTHUR WELLESLEY CLARKE, K.B.E., Elder Brother of Trinity House, and a Member of the Council of the Society. The paper and discussion will be published in the *Journal* dated April 13th.

CANTOR LECTURES.

MONDAY, FEBRUARY 20th, 1928. MR. HERBERT JOHN GOUGH, M.B.E., B.Sc., Ph.D., Engineering Department, National Physical Laboratory, delivered the second of his course of three lectures on "Fatigue Phenomena, with special reference to Single Crystals." The lectures will be published in the *Journal* during the summer recess.

FUND FOR THE PRESERVATION OF ANCIENT COTTAGES.

SIXTH LIST OF SUBSCRIPTIONS.†

	£	s.	d.
Amount previously acknowledged	4,723	2	0
James H. Hyde, Esq. (in addition to £525 previously subscribed)	500	0	0
G. Watson, Esq.	25	0	0
Mrs. Hilda Atkinson	1	1	0
R. F. Dodd Clarke, Esq.	1	1	0
F. H. Pryce, Esq.	1	1	0
Miss Beatrice M. Webb*	1	1	0
J. A. Savage, Esq.	10	6	
Miss Marie Yelf	10	0	
S. F. McKeen, Esq., M.D. (\$2)	8	0	
Miss Margery J. Watling	5	0	
	£5,253	19	6

The Council are extremely anxious to secure a generous response to the Prime Minister's Appeal, and they earnestly beg all those who have any feeling for the charm of the English countryside to subscribe to the Fund and to do what they can to interest their friends in the movement. Every day beautiful old cottages are being threatened with demolition, and unless help is speedily forthcoming many will be lost for ever.

A second edition of Mr. Baldwin's Appeal on behalf of the Fund has recently been issued as an illustrated pamphlet, and the Secretary will be glad to send copies to all who apply for them. It contains photographs and short accounts of Charles Lamb's Cottage in Hertfordshire, and the Thomas à Becket Cottages near Worthing, which have lately been saved by the Society.

† Previous lists were published in the *Journals* of April 8th, May 20th, June 24th, August 19th and December 6th, 1927.

* Annual Subscription.

PROCEEDINGS OF THE SOCIETY.**EIGHTH ORDINARY MEETING.**

WEDNESDAY, JANUARY 18TH, 1928.

PROFESSOR A. E. RICHARDSON, F.R.I.B.A., Professor of Architecture,
University College, London, in the Chair.

The paper read was :—

METHODS OF RADIANT HEATING.

By ARTHUR HENRY BARKER, B.Sc., B.A., M.Inst.C.E., Wh.Sch.

It is a commonplace of physical science that heat energy is transmitted from one place to another by three physical processes—by conduction, convection and radiation. It is probable that these three are ultimately the same. In order that the present discussion may be understood by those who are unfamiliar with elementary scientific ideas it may be said that :—

- (1) Conduction is the process by which particles of a solid body become heated from hot adjacent parts in so-called contact with them.
- (2) Convection means the carrying of heat by relatively hot molecules of a fluid floating into contact with relatively cold particles of another body.
- (3) Radiation is the process of conveying heat by rays travelling in the ether like rays of light.

The warming of a room is not by any means the simple matter which one might be inclined to think. On the contrary, it is so complicated that the human mind cannot fully grasp it, but it is necessary that a certain conception or mental picture of the process should be in the minds of any person hoping to understand, in however elementary a manner, the methods employed. Even at the risk of appearing tedious it is necessary to give as brief a description of the process as I can put together so as to be intelligible.

It should always be remembered that a human being is kept warm not from without but essentially from within, that is, by chemical processes proceeding in the interior of the body, which furnish to the body a continual supply of heat derived ultimately from the combustion of the food substances. It is necessary for the well-being of the body that it shall always be kept at a constant temperature.

Since, therefore, nature is continually providing to the interior of the body an uninterrupted supply of heat it is obvious that heat must accumulate there (in other words, that the body must grow warmer and warmer) unless the heat is removed as rapidly as it is produced. Hence the environment (by which term is meant the surrounding air and the surrounding surfaces) must be at such a temperature and in such a physical condition as to remove this heat

exactly as fast as it is generated, no faster and no slower. Such are the prime necessities of the human body.

One of the most marvellous mechanisms in the whole of nature is the method of thermostatic self-regulation by which this balance of heat is maintained in spite of a constantly changing environment. It operates in two ways:—

(1) By controlling the rate of production of body heat according to the environment.

(2) By regulating the rate of dissipation of the heat already generated according to the body temperature.

The perfection of the process is secured when the person concerned is unconscious of any discomfort or variation of condition. If the state of his body and the conditions of the environment are not perfectly correlated the individual is vaguely conscious of a strain on his thermostatic body mechanisms. The evidence of the strain takes the form of a feeling of cold on the one hand, or of heat on the other. If the environment is exactly suited to the condition of the individual at the time he will be completely unconscious of it.

Now comes the part of this extremely complicated process which is so difficult to understand: that is that the feeling of cold or heat in an individual is not necessarily a measure of the actual rate of heat loss from his body as compared with the heat generation, but that it depends not on the amount but on the ways in which the heat is abstracted from the body and which control the generation of heat.

Some conditions stimulate the production of heat to correspond to changes in the environment and some tend, instead, to increase the dissipation of heat instead of controlling its generation.

The sensation of cold can be avoided in two ways: one, by raising the air temperature around the body up to a certain suitable degree, generally about 65–70°, depending on the degree of humidity of the air; or, secondly, by allowing radiation from warm objects to impinge on the body, the air temperature being at a much lower degree than this.

The difference in effect between these two processes is very great. If the heat is supplied by warming the air an undefinable feeling of stuffiness is produced which is very difficult to describe but very easy to appreciate. The reason is that this kind of heating causes the heat to crowd up in a person's body which sets to work nature's mechanism for dissipating the heat into the surrounding hot air, and this process is attended by a feeling of stuffiness.

A person who is kept warm by radiation in cool air on the other hand, as, for instance, on a cool day with bright sunshine, feels warm and fresh. The reason is that the coolness of the air stimulates Nature's mechanism to produce as much heat as required and to dissipate the surplus easily while the effect of the radiation on the body prevents it from feeling cold, which is a superficial nerve effect.

The difference is not, as is commonly supposed, a question of chemical purity of the air, but of the way in which heat is communicated to the person's body

or on balance abstracted from it. If one were to endeavour to measure these two different conditions by means of a shielded thermometer one would find that in the first case the thermometer would stand much higher than in the second. The person would actually be no warmer in the hot air, but he would feel undefinably stuffier, and if he did not understand the matter he would say that the air was bad in the one case and good in the other. The real effect has nothing whatever to do with the chemical quality of the air.

In the light of these facts, difficult as they are to understand, let us consider the two corresponding methods of warming a room.

We are able to warm a room in two ways: one by convection currents of heated air, and the other by introducing, somehow or other, radiation into the building.

These two processes, though they may be originally distinct, very rapidly merge into one another in the room itself because of the nature of heat.

Thus, if we allow the currents of hot air to play on a light screen, the latter very soon gets hot and begins to radiate heat to the other objects in the room. Similarly, if we place the same screen in the path of a beam of radiant energy, as from a gas fire, it also gets hot and warms the air in contact with it, thus generating convection currents. It also begins to radiate heat on its own account.

It will be seen, therefore, that if we keep radiation and convection distinct in their origin, and arrange a certain proportion between them, that proportion is immediately disturbed as soon as the heat gets loose in the room.

In order to keep our minds quite clear in considering this very elusive problem let us consider the physical effects of warming a room by pure convection and by pure radiation respectively.

To fix ideas, assume that the room is initially in a uniform condition in which the thermometer reads 32° , and has been in that condition for so long a time that the air, all the furniture and the surfaces of walls are at the same temperature. Into this room we introduce a continual slow stream of warm air at, say, 95°F. , thus displacing and forcing to the outside an equal volume of cold air. This warm air immediately on its release into the room will rise to the ceiling and will stay there with the warmest layer, at first, close to the cold ceiling, which will gradually transfer some of its heat to the cold ceiling, which thereby becomes warmed, and the air correspondingly cooled. The warm air at the ceiling is continually displaced by a fresh layer of warm air coming from our original stream.

Each successive layer is continually forced further and further downwards by the introduction of fresh warm air. At any moment, therefore, we get a series of layers, each cooler than that above it, the series extending downwards towards the floor.

After th's process has continued for some time some of the warmed air has been gradually forced downwards to the floor, where it comes in contact with the furniture, which is gradually raised in temperature.

At the same time as this process is going on the opposite process will also go on of the cooling of some of this warm air. Some of it will come in contact with the cold window surfaces, where it will be cooled and at once sink to the floor. It will be succeeded by other layers of cooler air generated by the cold windows. It is precisely the same process as the heating process, but in the opposite sense. We get ultimately a series of layers of different temperature, the coldest layer on the floor and each layer above it warmer, the series extending from the floor to the ceiling.

Thus the ceilings, walls, furniture and other objects in the room will get warmed or cooled by the air, according to the position in the room in which they are placed. As soon as any of them gets warmer than its surroundings it begins to radiate heat and to generate convection currents on its own account, and not until all the surfaces have been made so warm that they will on the whole radiate heat to a certain average intensity does a room feel reasonably comfortable. Until that stage is reached the loss of heat from the body of a person in the room, caused on the one hand by the cold radiation, and on the other by the movements of cold air currents set in motion by the heat, produces a feeling of discomfort which we summarise by saying that the room is too cold.

Now consider the opposite process—the process of heating the same room by radiation.

If we imagine a powerful beam of pure radiant heat proceeding in all directions from a compact incandescent mass introduced into the room. The rays of energy proceeding from the incandescent particles on the surface of the mass travel in straight lines through the room and impinge on the solid particles of the walls or furniture. Each such ray there partly absorbed and partly reflected. The absorbed part warms the surface where it impinges. The reflected part again traverses the space in the room and again impinges on some other solid point where the secondary rays are again each partly absorbed and partly reflected, and so on. Thus we get in the interior of every room and through every portion of the space a multitudinous confusion of rays of all sorts of intensities passing in every direction from every one point to every other point.

If the beam is sufficiently powerful a person in the room, however cold the air is, feels comfortable immediately the beam is started. The direct rays strike him and make him feel warm, or even hot, at once although the general temperature of the room may be very low.

The rays of the beam that do not strike the person strike the walls and furniture where they are reflected. Some of the reflected rays strike the person and have exactly the same effect but of reduced intensity as if they had proceeded from the point from which they are reflected.

The effect of the radiation is therefore to produce immediately what I have elsewhere called a virtual temperature at all exposed surfaces which is considerably higher than their real temperature. In course of time the proportion of the

heat absorbed at these surfaces raises their actual temperature and they begin to radiate heat on their own account. Thus both the primary, reflected and secondary rays strike the person in the room, and when this happens the room may feel too hot, whatever the actual temperature of the air may be. In order to make it comfortable some of the original radiation must be cut off or reduced. So soon as the surfaces become warmed by absorption of the radiant energy they commence themselves to heat the air and the convection process also begins. It will thus be seen how extremely complicated the process is.

To determine the degree of heat comfort felt in a room, or to define the exact thermal condition at any particular moment, is one of the most difficult things in the whole of applied science.

The practical means of warming an interior is invariably to introduce into it some body at a higher temperature than the general interior, and to allow the heat from the hot body to pass by the various physical agencies to the air and the other objects in the room.

The surprising thing is that so little consideration has been given in the past to the physical means by which the distribution is effected from the hot vessel to the room interior and to the effects produced by the different means.

It is equally surprising that the method adopted up to within very recent times has been very largely the use of the convective method of distributing heat.

We are here up against the very heart of an extremely difficult and elusive problem, the real nature of which cannot even be understood without a good deal of careful thought, nor adequately explained without much care.

It is evident that the primary and really the only object of warming a building is not to raise its temperature for its own sake, but to make it feel comfortable for persons to inhabit. We only raise its general temperature (which is an expensive process) as one means of making it feel comfortable. If we could produce that effect without incurring the great expense of raising its temperature we should obviously do so.

General experience shows that when the reading of a thermometer in an ordinary building is between certain limits, say from 58° to 70°, the building is commonly regarded as comfortable.

If the reading is below, say, 55°, most persons would find it too cold and above 70° too warm for comfort. Such is the experience in an ordinary building heated for sufficient time by ordinary means. The thermometer temperature, has, therefore, come to be regarded as a measure or criterion of heat comfort. This is a very narrow view. It has a limited application when applied to the special case of an ordinary building which has been kept warm by convection for a long period, but it is erroneous as a general principle because it does not take count of all facts, experience and observations.

Let us consider carefully the following facts and their implications.

If we are in an ice cave through which a blast of hot air passes we shall feel very cold although the thermometer reads as high as 60° .

But if we introduce into the cave a glowing mass of iron it might be so hot as to be intolerable when a shielded thermometer reads 32° . This is because of the reflection of the heat rays from the surface of the ice.

A cold room heated by a gas fire recently lighted may be very comfortable almost at once for a person within the range of the influence of the fire even though a thermometer shielded from the direct impact of the rays reads as low as 45° . Outside the range of the rays the cold might be intensely felt.

A few days ago I was in an experimental room near my laboratory in which a naked person was standing in perfect comfort when the temperature of the room was 42 degrees. The stand was surrounded by five hot panels, each about 1 foot square, fixed about 6 feet away radiating heat on the naked body.

Further, a person may feel perfectly warm in the sunshine in still air when the thermometer in the shade stands many degrees below freezing point. It would be intensely cold in identical condition if there were any wind, without any change in the thermometer reading.

It is perfectly evident, therefore, *considering such facts*, that, except in special cases, the thermometer temperature cannot be regarded as a true criterion of comfort. It will be seen, also, how difficult it is to lay down such a criterion of comfort in a room. One statement that can certainly be made is that whatever other instrumental means may ultimately be found to represent comfort correctly, certainly a plain thermometer does not, except only that when the method of heating and the thermal distribution are similar the height of the thermometer does give a sort of measure of the feeling of warmth. What is important to understand is that in radiant heating the thermometer is no guide to comfort.

It will at once be seen that the solution of this vital problem lies at the root of successful heating engineering. If the object of heating engineers is, as it obviously is, to make a room comfortable, and if we cannot with precision and certainty lay down what physical conditions do constitute comfort in a room, it will be seen that the whole scientific basis of heating engineering is in doubt. There is no time in one short lecture to discuss adequately this intricate technical question. We shall take it that a cold room can be made comfortable to inhabit by introducing in some way an adequate quantity of radiant energy, and it is a matter of experience that if the heat is introduced in an appropriate manner the amount of heat required is distinctly less than if the heat is introduced as convection currents.

The principal object of this paper is to discuss the methods of radiant heating and not heating in general.

We have, then, to enquire how, and in what form, we can introduce this radiation into any building and what are the different practical means available.

Generally we can divide the methods into two classes, one high temperature,

or incandescent, methods, and the other low temperature, or distribution, methods.

The former consists in maintaining some radiating body at a high temperature at which each point of the hot surface gives off a beam of rays. Such a beam is of a number of different wave lengths extending far down into the infra red, and in such a beam infra red rays carry the most energy, though the luminous rays, from the green downwards, are of importance.

In the case of the other class, or low temperature methods, the radiation is produced from a larger area of surface maintained at a much lower temperature. These surfaces are exposed to the interior of the room and give off beams of rays, all of which are in the infra red region ; that is to say, the beam they give is entirely non-luminous and invisible.

It is found by experience that radiant heat of this character can be utilised to make a room comfortable at a much smaller expense of energy than when the radiation is of a luminous character. The reason probably is that glass is much less diathermanous to rays of longer wave length, and much more so to waves of shorter length. Thus a large part of the heat when introduced as luminous waves passes through the glass of windows and is lost. Also wall surfaces will absorb a much larger proportion of the luminous heat impinging on the walls of a room, but heat is absorbed by the surfaces, and is rapidly conducted to the outside, and is lost in the outer air, whereas a much greater proportion of the dark heat would be reflected back into the room.

Such is the difference in effect.

I do not think that it is possible for anyone to distinguish by sensation incandescent heat from the dark variety.

The sensation effect of a given intensity of radiation on the skin is probably the same in all cases irrespective of wave lengths, although of this fact I am not absolutely sure. It does, however, appear probable that the physiological effect of light and dark heat must be different. It is probable that the bright heat is more physiologically advantageous than is the dark heat.

That is a question on which I am not competent to pronounce from my own knowledge.

The incandescent method essentially requires some highly concentrated supply of energy in the form either of solid fuel or of gas, oil or electricity. By any of these means it is possible to produce the incandescent effect which is required.

These methods may roughly be divided into two classes of which the first consists of the emission of radiation from the burning fuel direct, such as the coal fire. The second method consists in the heating up of some material of a high emissivity, which can be raised in temperature directly or indirectly by the combustion of fuel. The necessity for this latter method arises from the fact that the energy of combustion of some fuel is very largely carried off in a convective manner. Thus, a mixture of gas and primary air emits very little of

the energy of combustion in the form of radiation, but when this gas flame is allowed to impinge on material such as fire-clay, it is raised to incandescence and gives off a greatly increased part of the energy in radiant form.

Electric power is similar. If one were to raise a coil of, say, nichrome wire to incandescence by means of an electric current the amount of energy given off from it in the form of radiation would be relatively small, but if the coil is enclosed or enshrouded by fire-clay in close contact with it the fire-clay itself becomes incandescent and the amount of radiant energy is greatly increased.

For countless years methods of heating by incandescent radiation have been in use, of which the oldest, and by far the commonest, is the old open coal fire, which allows the greater part of the convected heat to escape up the chimney with the smoke and distributes the remainder, in the first place and in the main, in the form of radiant energy.

This method, many as are its advantages, is, of course, about the crudest and most extravagant that could easily be conceived. Functionally it consists in using up the energy of the sun which has been distributed over the earth ages ago and has been chemically absorbed. Early discoverers found this deposit of concentrated energy in the earth in the form of wood or coal and found that by setting it alight they could release its energy again and use a small fraction of it. No considerations of economy in its use entered their heads. This aboriginal discovery has been used in that form ever since, and doubtless will continue to be used for many years, though not, I think, for ever.

The device for economising this fuel by enclosing an open fire in a casing and calling it an anthracite stove entirely transforms the character of the heat obtained. The radiant heat from the fuel is absorbed by the walls of the stove which is thereby heated and distributes about 70 or 80% of the heat in convection currents. The remainder is radiated at a low temperature. Some slow combustion stoves have a very high efficiency, indeed, 90% being not unknown, but the greater part of the heat is convective and in so far does not come into the present discussion.

This open fire process has been improved in efficiency, convenience and economy, by extracting from the solid fuel a gas of which the advantages are that it is readily carried to the point where it is to be burnt and that its combustion leaves no solid residue, and that the rate of combustion can be regulated by a tap. These are very great advantages. Functionally the effect of a gas fire is identical with what has been already described. There is no difference between the physical effect of heat from a coal and a gas fire properly fitted with a suitable flue. The idea that a gas fire provides drier radiant heat than a coal fire is merely absurd. Given the same chimney the only real difference between them is the attractive and capricious variability of the one and the controllable constancy of the other—that is a difference which the wise makers of gas fires should try to reduce.

Gas can also be used for the local production of luminous radiation, but not without the generation of a corresponding amount of convection. The type of apparatus known as the bowl fire now becoming fairly well known is extraordinarily useful in certain circumstances. This appliance has an incandescent mantle at the centre of a large hemispherical copper reflector. It distributes approximately 45 % of the energy of the gas in the form of a beam of radiation which can be transmitted over considerable distances through a room as the beam is only slightly divergent. It is possible with three or four of these appliances at the corners of a large cold room to direct a beam of heat on a person sitting in the centre of the room in such a way that he will feel perfectly warm. The drawback of their use is, of course, the generation of the products of combustion which foul the reflector and which must either be allowed to mix with the air of the room or be got rid of somehow. A more desirable though more expensive type of similar character is the electrically-operated bowl fire, which for certain purposes provides a very desirable type of local luminous radiant heat.

When used in the manner described above a person can be kept in complete comfort in a dead cold room by directing beams from two or three of these heaters on his body from a distance. Even a perfectly naked person in an absolutely cold room can be kept quite comfortable.

The ordinary electric fire does not usually distribute more than from 40 % to 70 % of its heat, according to type, in the form of radiation, the remainder being convection. They are too well known to need further comment.

Most of the other heating stoves are largely convective in character.

A type of electrical fire now becoming rather well known is a clever imitation of a coal fire, being so arranged to present a similar appearance. Reflectors are arranged to radiate a certain amount of heat from the front.

Though very desirable in certain positions in well-to-do homes, they are expensive both in first cost and in current consumption, especially if any considerable amount of heat is required.

Functionally, they provide a mild beam of radiation of which a relatively large proportion consists of light-giving rays. They are often so placed that a considerable portion of their heat is wasted as far as the room warming is concerned. They should never be placed under a chimney. Only about 30 % of the heat given off is radiation, the remainder being convection.

We now turn to the consideration of the appliances giving dark heat.

The essence of this method is to maintain exposed to the room interior a large surface at a medium temperature, usually not exceeding 120 deg., but which in some examples is very much higher. About 60 % of the heat given off from such a plate is usually in the form of radiation and in some cases, I believe, much more, depending on the movement of the air in contact with the plate. An ordinary radiator does not give off more than about 12 to 15 % of its total emission in the form of radiation.

There are many disadvantages in maintaining a high temperature, both because of the danger and of the unpleasant character of the heated air it gives off, due to charring of ammoniacal dust particles ; also on the score of economy. Any given amount of heat spread over a large surface at a low temperature is much more effective in producing a feeling of comfort in a room than if the same amount of heat is spread over a smaller surface at a higher temperature. Thus there is (as is very often the case) a conflict between first cost and economy of upkeep. The higher the first cost the smaller is the cost of upkeep for the same heating effect.

The principal advantages of this radiant method are that it dispenses with the feeling of stuffiness which always exists to a greater or less extent when the means of transmission are purely convection, and which forms the principal obstacle to the general adoption of central heating. The second and outstanding advantage is that a large reduction on the cost of heat is effected by it. I believe that the convection type of heating will be carried out in future only in places where it is necessary to heat air or to distribute the heat in complicated chambers, or where it is impossible to find adequate space for radiants on the walls or ceilings where the hot surface will not be obstructed.

One of the drawbacks is that the effect of the hot surface is diminished in situations where an unobstructed view of the heating surfaces is not obtainable. If the hot surface is out of sight its effect is a good deal reduced. This implies that more heating units are necessary than would be required with convective structures, which tends to increase the first cost. Where the heating surface is placed on the ceiling it can hardly be obstructed by furniture. It is, therefore, likely that in future heating will often be done by a surface of this character fixed on the ceilings, though this position has also its disadvantages, especially the danger of damaging tables and other furniture placed immediately below, and the floors immediately above.

The methods that have been evolved are numerous. The first method used in practice was, I believe, originally conceived by myself during certain experiments made in my own house.

There were two rooms side by side of about the same size, of which one always felt warm and the other relatively cool when the thermometer temperature was the same. I found this was due to the circumstance that the average temperature of the walls of the one was several degrees higher than that of the other owing to the presence of certain flues in the wall which increased the feeling of warmth without considerably raising the temperature of the thermometer. I therefore conceived and patented the idea of warming the walls directly by burying small hot-water pipes in the plaster, through which hot fluid could be circulated. The heat of the fluid was thereby transmitted by conduction through the pipes conveying it, and through the plaster to the surface which thereby became warm.

Various practical methods of accomplishing this result have been developed since that time. Originally it was proposed to cast the pipes in a separate slab of special plaster material of a quality which would not crack by the heat, to be built into the wall. Afterwards it was found practically possible and more convenient to cast these slabs in position on to the wall by first putting up the coil connecting it to the circulating pipes and covering it with the plaster. The drawback arising from this alteration is the difficulty of avoiding a cracking of the plaster unless the temperature of the water is kept very low. Many different kinds of plaster have been tried, and even at present a wholly successful solution to this problem has not yet been found. Later, with the development of concrete buildings and concrete floors, came the proposal which has been extensively used, to cast ready-made steel coils in the concrete of the walls or ceilings, especially the ceilings, the pipes all being welded together and completed before the concrete is cast. Thus the pipes become firmly imbedded in the concrete, and any hot fluid passing through them will have the effect of heating the mass of concrete and producing a warm building without unduly heating the air.

It is evident that when coils are completely concealed in the structure of the building it is a more difficult matter either to keep track of them to repair, or to increase, or to reduce them in size, or cut them out of circuit, or to clear them if they become stopped up, or to alter them in any other way when the building is altered, than if the pipes are all exposed and accessible.

Efforts have been made to obviate some of these difficulties of imbedded coils by applying the heat to the ceilings or walls in other ways which will not involve embedding the pipes and soaking the heat in the structure where it is undesirable. One method of recent introduction has been to form the warm panels in the shape of a large flat surface of cast, or wrought, iron on which are formed the conduits for the conveyance of the hot fluid. The heat of the fluid passing through this conduit communicates its heat to the metal which spreads out over the plate until the whole of the surface is warmed.

This has an advantage over the plaster coil that the entire panel can be removed without damage to the structure and replaced after having received any attention that it may require, also that it can be served by water or steam at any temperature without fear of producing cracking of the structure.

The disadvantages of it are that provision has to be made for supporting the panels which are often of considerable weight. They are fixed either on the ceiling or on the wall by screwing them to specially-made brackets bolted in appropriate positions to the structure. It is not always easy to conceal the pipes serving the panel without burying them in the plaster where they are inaccessible. For this purpose a special dummy plate is sometimes made to cover up the connections.

In cases where economy is of greater importance than artistic appearance the panels may be bolted direct on the wall or ceiling and left exposed without

any kind of concealment. In the opposite conditions where complete concealment is of importance, the panel is let into a recess formed in the wall or ceiling. The panel is provided in the form of a perfectly flat plate, the face of which is fixed flush with the wall or ceiling surface, or, if not absolutely flush, it may project slightly in the form of a panel which may be arranged as a part of the decorations. It may then, if desired, be covered with a thin veneer of metal, or otherwise, which shall be flush with the wall. The edges may be confined by a beading or frame, or otherwise.

In other cases the panels are formed as a complete, or partial, dado round the walls.

The plates are cast from patterns made like an ordinary oak dado, in which oak graining has been incorporated, so that when suitably coloured they have the exact appearance of genuine oak ; indeed, it is impossible to distinguish them in appearance from ordinary panelling made of oak or other wood. The master patterns are actually first made in genuine oak. They are then treated with a sand blast which has the effect of cutting out the soft parts of the wood between the hard veins, thus emphasising the graining. Iron patterns are then cast from this wood pattern, which are again used from which the final castings can be cast in large numbers, each bearing the exact appearance of the oak graining of the original wood pattern. This method is very much cheaper than real oak panelling.

Naturally in the mass production of castings an oak pattern would soon be destroyed. The effect produced by the iron patterns is exactly similar.

The metal panel also lends itself to use which will probably become very general, with gas or electricity as the heating medium. A gas flame is arranged behind the panel, which will supply heat all over the plate. The products of combustion are sucked through the conduits by a small extract fan which withdraws them and discharges them to the outside. By this means the panel is warmed all over, the same effect as when heated by water or steam.

In a similar manner the passages in the panel can be supplied with electrical coils through which a current of electricity from the power mains will generate the necessary heat which is distributed by the plate all over the surface.

The effectiveness of this form of heating makes possible heating by gas or electricity in many cases where the expense of convective heating would be too great. This renders possible the central heating by gas, especially of buildings where no flues are provided and without the products of combustion contaminating the air of the building. Automatic devices are supplied by which the gas is turned off if the suction fails so that there may be no danger of escape.

This application has also the great advantage that the whole of the gross heat in the gas is employed, that is, the products of combustion on reaching the fan are generally absolutely cold so that although no products of combustion are introduced into the building no heat is thrown away in the products. This effects a very large reduction in the cost of heating a building of any size

without a boilerhouse, and without the trouble of carting fuel and ashes, and makes possible the heating of a building without flues by gas at a cost of about half the usual cost of heating by gas and which does not greatly, if at all, exceed the cost of heating by hot water radiation, especially because of the ease of control. The gas can be turned off at once when not required. It is certainly immensely below the cost of heating to an equal degree either by open coal or gas fires.

Similar results can be obtained by enclosing in the conduits an electrically operated coil which in the same way distributes the concentrated heat derived from the consumption of electrical energy over the whole of the plate and enables all the room to be heated electrically at about half the cost of heating by ordinary electrical radiators.

Other means which have been adopted to secure a similar end have been to cover recesses left in the wall and fix steam coils covered in with a sheet of iron or other metal. In this case the heat of the steam pipe which would be very objectionable and even offensive in a room on account of the burning effect of a high temperature surface on the air heated directly by the coils is confined and diluted in the space covered by the steel plate, and is transmitted to the room at a low temperature.

Other methods of warming panels by means of electrical energy have also been introduced.

Similar effects have been produced by textile means in which a continuous wire is inwoven with the cloth, the wires being the warp and the wool or silk the weft and electrical current passed such a material, when in good order, causes the cloth to be uniformly hot all over. It is commonly used for pictures and seats of chairs and the like, or screens. It has the advantage of lightness and portability and the disadvantage that a possible fracture of the electrical conductor might occur, in which case naturally the current will be cut off. There would also be the danger of a user receiving an electrical shock if anything went wrong with the terminals or connections.

Radiating surfaces of several unique kinds have been, and are being, made. One of the most notable is the heating of large glass mirrors by the insertion of an electrical resistance circuit behind which warms up the glass and produces the same effect. Similarly, metal plates have been treated by fixing to the back of them electrical coils of suitable resistances, whereby the plate is warmed uniformly all over.

Other methods of carrying out this principle involve the heating the floor by various means.

This method is not strictly what is meant by radiant heating. It is, perhaps, a combination of all the three agencies—conduction, convection and radiation—though it is difficult to lay down a proportion between them. It is a great difficulty, well known to Heating Engineers, that in an otherwise well warmed large building or hall, such, for instance, as a theatre, or cinema, even though

the space as a whole is well warmed by convection methods, the floor is apt to be very cold, especially under the seats for reasons which I have already explained. The audience in such places frequently complain of cold feet when the general temperature is so high as to be stuffy, especially at the gallery level. This is one of the most pronounced examples of the disadvantages of heating by convection, and is a direct consequence of the inherent defects of that method.

Continental engineers, and to some extent British ones also, have attempted to overcome this defect by withdrawing the extract air through gratings underneath the seats where these are fixed. This, at any rate, ensures that a certain amount of warm air shall find its way to the central parts of the floor.

The general method of floor heating was in use many centuries ago. It was certainly known in Roman days, when houses and baths were sometimes heated by forming flues under floors and in the thickness of the heavy walls of the buildings of those days, which were heated by basement fires.

This method, excellent though it was, fell into disuse, and was probably not thought of for the next thousand years or more. The general principle was revived some years ago in a slightly altered form, and has been used, among other buildings, in Liverpool Cathedral.

One method of its application is to heat air by means of stoves of different kinds and force it, by fans, through long flues extending the whole length or width of the floor area to be warmed, whereby the temperature of the floor is raised.

It is not possible or desirable to force the products of combustion through these flues, firstly, because of their high temperature, and, secondly, of the tendency in course of time to accumulate soot and flue dust, which is difficult to remove. Even air is not an ideal medium for conveying heat, because of its relatively low specific heat compared with its volume. A large amount of air has to be forced through at a high velocity in order to convey an adequate quantity of heat, and the temperature is apt to fall in a marked degree from one end to the other of the flue which involves a difference in temperature over the area of the floor. Any temperature higher than perhaps 65 or 70 degrees on the surface of the floor becomes very uncomfortable for the feet, while if it is below 60 degrees it is not of much use for heating. Hence the limits are very narrow.

Another, and in some respects a better, method is to provide hot water pipes under the floor in shallow trenches filled with sand and covered with concrete or other slabs, which may be made more or less removable for access to the pipe if and when such access is found necessary.

This method sometimes involves difficulties in venting the pipes, which are apt to become air-locked.

The method, too, is subject to the disadvantage that if the floor is covered with wood blocks, those situated immediately over the pipes are apt to shrink under the influence of the heat and become detached.

This method has been frequently used in open air schools and sanatoria and like buildings, where very free ventilation is necessary.

The principal disadvantage of the method is that it involves considerable cost in builders' work, and that a repair or adequate inspection of the system involves taking up the floor and this is a disadvantage of all systems which involve the incorporation of any pipes or any part of the heating plant with the structure itself.

I have thus very briefly indicated the methods in current use for adopting this valuable principle in the heating of buildings, and indicated some of the practical difficulties involved.

Most of these difficulties are esthetic ones, and arise in consequence of the increased attention given to appearance in modern buildings.

The modern radiator and pipe, though of immense value in central heating, are not articles whose inherent beauty would lead to their inclusion in any scheme of decoration.

On esthetic grounds it is very desirable that a building should be heated without the source of the heat being visible, but heat cannot be conveyed without pipes or flues. If these are hidden, and have to be inspected or altered, the consequent difficulties are obvious. There are very few kinds of working apparatus of any kind which will operate without some kind of attention, re-conditioning or alteration, for a long series of years. Our improved methods often involve increased difficulties in maintenance and repair. In practical applications we have to ask ourselves what will be the position of affairs at the time, which is certain to come sooner or later, when a thorough overhaul or repair of the whole system becomes necessary. We may, in some cases, comfort ourselves with the reflection that this necessity will not arise in our time, but it does seem that due weight should be given to that important consideration.

DISCUSSION.

THE CHAIRMAN said that, looking at the matter from the architect's standpoint, architects spent half their time arguing with engineers about methods of heating, and the other half in trying to convince the client that everything was all right. He himself had had experience of practically all forms of heating, from ordinary coal fires to wall radiators concealed so well that very little heat came from them. He had also used the balls of fire the author mentioned, and had complaints from clients who had fallen out of bed and burned themselves against them. The architect had to rely largely on the engineer in these matters.

As a mere architect with some experience of heating, it appeared to him that in the old days—what might be called the dark ages—incandescent heat was used, whereas, in the present light ages, one seemed to be using dark heat.

Occasionally, as he sat by the fire with a book, being burned by the beams of heat on one side and feeling frozen on the other, he seemed to hear the voice of humanity from the mists of antiquity onwards—the Roman slaves groaning as they fed their fires, the Saxons gathering round their huge central fire, the mediæval monks hurrying to the "warming chamber" after a cold service, and the people of the

eighteenth century in their large rooms shivering over a fire in a state of extreme chilliness. During all that period humanity had been trying to get warm. The ingenious Sir John Soane, in 1790, actually installed a heating system with pipes at the Bank of England which, he believed, was at work until the '70's.

Then came the Victorian period and the nautilus stove. The nautilus stove still existed, more especially in some country churches where draughts, smoke and the smell of burning were a predominant feature. There were nowadays also those terrible gas fires, which defiled the air of the room and wasted the gas so that the gas bill became terrific. There was also that other abomination, the oil stove, which some people placed in their bedrooms, and which blackened everything if it were left alone for a minute.

Architects had difficulty in deciding on the right form of heating to use. The author might be said to have given an analysis of discomforts, but, personally, he was still looking for something which would warm him upwards and all round.

So far as heating the naked body was concerned, the author had mentioned that, and he himself had been consulted about it. The Slade models complained of the cold, while the Slade students who were sketching the models complained of the heat. He was asked by the head professor for suggestions, and he proposed a box with some form of electrical energy rising round the model, and advised the professor to see Mr. Barker about it. Mr. Barker had arranged for a series of radiators round the model.

Both architects and heating engineers had a tremendous task before them. People were asking for warmth in winter; they could not stand leaving their one fire and going to a cold bed. Even the hot water bottle was useless. Sometimes clients asked him for 75°. He told them that that was quite possible, but that the furniture would go to pieces, and if they insisted on it that was what in fact occurred. Other clients wished to conceal the radiator and have it put below the floor, and afterwards complained that no heat came up from it.

One liked to cling to the æsthetic thrill of the ordinary fire. In the next room was a most remarkable fire, designed on economic lines by a Scotsman—Adam. It had been working since 1774, and still functioned. The whole fire-place was a radiator; it was not one of those improved modern fires which left the floor quite cold.

The smell and appearance of a wood fire was delightful, but he had no use at all for those imitation fires worked by electricity, which he regarded as abominations, as he did, also, the electric sham needlework heating apparatus. That sort of thing was a sham, and he did not want to have anything to do with it. If heating plates were to be put on the wall—and he thought it was a good idea—they should be put up honestly as heating plates and not made to look like oak.

MR. LLEWELLYN B. ATKINSON (Past-President, Institution of Electrical Engineers) said he had frequently over many years discussed heating questions with the author. A great change had come over people's ideas on the question of heating. When he was a boy he attended a school which was heated by vast volumes of air warmed to the temperature of the room and forced through pipes which were filled sometimes nearly an inch deep with dust. The idea was to fill the whole place with air warmed to a suitable temperature. Then came the days of hot water radiators, which only radiated twelve per cent. of their heat. Gradually the idea was reached of sitting in a cool room—cool so far as the temperature of the air was concerned—and being warmed by putting sufficient radiant heat on to the surface of one's body. The requirements of different people in that respect were so different that in many

families it was the greatest source of discord that existed. Some people liked to sit and sleep in a room with all the windows open, while others could not stand it. Personally, for six or seven months a year he slept in the open air altogether, but his family would not wish to do that.

One point the author had not touched on at all, but which he thought was very important, was the question of humidity. Personally, he thought part of the difference between sitting in a room with cool air and radiant heat and sitting in a room where all the things were of nearly the same temperature turned largely on the question of humidity—the percentage of moisture in the air. Most people had an idea that the air in winter was very wet, while in the summer it was very dry, but that was not correct. The percentage humidity of the external air was as a rule not very different all the year round, but in winter, when the temperature was low, the number of grains of moisture in the air was low as compared with the condition in summer. That was so far as the air outside the house was concerned. The moment the air came into the house and was raised to the same temperature winter or summer the air became very much drier in winter than in summer. That caused a greatly increased evaporation from the body, and some of the effect of apparent stuffiness was really due to the fact that one was evaporating far too much moisture as a result of raising the temperature of the air and so making its relative humidity very much lower. One should not only hang up a thermometer in the room, but also a hygroscope, which showed the relative humidity of the air, and if that were done surprising results would be found.

Dr. Ferranti had an all-electric house near Buxton, and, living away from the general source of supply of electric current, he had installed a very large oil engine worked by heavy oil. That engine required a considerable amount of cooling water, which was heated by the engine, and then carried through over in the ceiling in the way the author had described, so that the house was heated with the waste low temperature heat which was of no other use. For those who wanted direct radiation there were electric radiators, and the house was fitted with electric light, electric cooking and electric motive power. Nearly the whole of the heat generated by the burning of the oil, therefore, got into the house in one shape or another, either as low temperature or high temperature radiant heat, or light.

DR. MARGARET FISHENDEN (Fuel Research Division, Department of Scientific and Industrial Research), said the author had emphasised the difficulties of the heating problem and suggested that the human mind was almost incapable of dealing with it. Personally, she preferred to take a slightly different standpoint; she agreed that the problem was very complicated, but there was nothing mysterious about it. The human body, like any other body, lost heat in relatively cool surroundings, both by radiation to cooler surfaces and by convection to cooler air. Although it possessed a wonderful regulating mechanism for maintaining its internal temperature always at 98°F., it was bound to obey the normal laws of heat transfer. The colder the surrounding surfaces, the more rapidly the body, for any given surface temperature, lost heat by radiation; and the colder the air the more rapidly it lost heat by convection.

If, however, a room was too cold the body heat losses were reduced by an automatic lowering of the surface skin temperature, although the internal temperature remained at 98°F.; and physiologists said that what caused a sensation of cold was the temperature difference between the surface skin and the deeper nerve endings. In the same way, if a room was too hot the blood vessels supplied blood right up to the skin, the body surface temperature rose, and a sensation of over-heating was created.

For any given air temperature, one could so adjust the temperature of other surroundings that the aggregate heat losses from the body would be about normal. Physiologists had discovered that comfort coincided with a skin temperature of about $92^{\circ}\text{F}.$; clothing would then be at about $75^{\circ}\text{F}.$ If all the surfaces round about were also at $75^{\circ}\text{F}.$, the body would lose no heat by radiation, and to remain comfortable, would have to lose as much heat by convection alone as it did normally by both convection and radiation in a room uniformly at say $65^{\circ}\text{F}.$

The essential difference between radiant heating and air heating, therefore, was that in the presence of a surface at a relatively high temperature which reduced the loss of heat by radiation from the body, one could put up with a lower air temperature.

There was a great deal of slackness in regard to the use of the expression "air temperature" in defining the conditions in a building. Taking an extreme case of a building or room made of corrugated iron, where there would be practically no temperature gradient in the metal, it might be assumed as an approximation that the inner wall surfaces would assume a temperature midway between that inside and that outside. In such a case, for comfort it would be necessary to keep the air of the room a great deal hotter in winter than in summer, because the wall would be much colder in winter than in summer, and to neutralise that a higher air temperature would be required.

The author suggested that panel heating was more economical than heating by incandescent surfaces; firstly, because the short wave lengths of incandescent heat passed more easily through windows than the long wave lengths generated by panel heating, and, secondly, because short wave lengths—in other words, luminous radiation—were absorbed more readily by wall surfaces than dark radiation. She was doubtful whether those reasons would explain an economy. In the first place, the angle subtended by windows at a high temperature radiating surface would usually be small; and, in the second place, the statement that the wall surfaces absorbed luminous radiation more readily than dark radiation was contrary to experimental evidence. It had been shown, both by Griffiths at the Natural Physical Laboratory, and by Coblenz at the U.S. Bureau of Standards, that the absorption coefficient for long wave radiation was very high for all surfaces other than metallic ones, but that as the wave length of radiation got less the difference between different surfaces became more pronounced. She felt inclined to look for an explanation in the better distribution obtained with panel heating.

It was a common fallacy that the closed stove gave a low percentage of radiation. Unless there was some special provision for the circulation of air, a closed stove gave a high proportion of radiation, but it was not concentrated radiation like that obtained from an incandescent fire. Several investigators had shown that surfaces, unless of bright metal, even when only a few degrees in excess of the surroundings gave 50 per cent. of radiation and 50 per cent. of convection. The reason why hot water "radiators" gave a low percentage of radiation was not because their temperature was low, but because their surfaces were so packed together that the radiation emitted was prevented from penetrating into the room. Such radiators had a bigger effective surface for convection than for radiation.

The reason the open coal fire gave a high proportion of radiation was not because there was no convection; but the warmer air was lost up the flue and the radiation was all that got into the room.

She understood that the first application of steam heating was what might almost be described as panel heating. It was recorded that Watt, in 1785, attempted to warm a room in his house by steam, and the way he did it was to make a box, some 3ft. square, and pass steam through it. Unfortunately, this was before

Leslie had shown that polished surfaces did not emit much radiation, and as the box was made of tinned iron, Watt was disappointed with the result he obtained.

MR. C. INGHAM HADEN (Past-President, Institution of Heating and Ventilating Engineers) thought that as the author had referred to Liverpool Cathedral it might be of interest if he gave a few particulars of what happened there. Dr. Fishenden had spoken of the panel being so effective because of its increased area. If Liverpool Cathedral had been fitted with hot water radiators sufficient to heat it in the ordinary way it would look like a radiator showroom, whereas in fact, there were no radiators to be seen on the floor level of the cathedral. The floor of the cathedral might be called the largest radiator in existence in this country at the present time, and when the cathedral was completed it would be still larger. It had been found that the temperature from the floor to a height of 117 ft.—which was the height of the cathedral—varied but very slightly. There was a triforium in which was a separate system of heating apart from the floor. He himself argued that although that system for heating the upper air of the cathedral had been provided, he felt sure it would be possible to obtain all the results desired without it, and therefore experiments were carried out to determine the value of the heating with and without heating the upper air. Ninety-five feet from the floor level the drop in temperature from 5 ft. above floor level was found to be $1\frac{1}{2}^{\circ}$, and when the upper system was put to work there was no difference at all—not even of a degree—in the temperature at different levels. It seemed to him that proved that in the air, which was gradually intermixing all the time in the cathedral, there was no strong current anywhere. There were so many small currents intermixing that the temperature thereby became practically uniform. Although power was provided to raise the temperature to 60° , it had not been found necessary to keep it at more than 56° , which had been found the most comfortable temperature owing to the fact that the humidity of the air in the cathedral was only 10% less than the external atmosphere. That proved that the larger the radiating surface at a lower temperature the better was the heating effect. As far as appearance was concerned, one had all that could be desired when the floor itself was of marble, and this being used as a radiator, people did not suffer from cold feet, the temperature being on an average 70° or 28° less than the temperature of the body, so that the heat was not too great for comfort of the feet.

PROF. F. L. HOPWOOD said one problem had not been touched on that evening which affected everybody, namely, the heating of the bedroom or the sick room. There the naked body was not usually being exposed, but only the minimum portion of one's surface, and it was all important, considering the large amount of time spent in a bedroom—larger than in any other single room—to know something about the heating of bedrooms, and particularly sick rooms or hospitals.

MR. GEORGE NOBBS thought it obvious that panel heating was the best kind of heating for comfort, but beyond that very little was known about it, because the system was quite new. It would be of interest to know whether electric heating could be applied to the panels.

DR. ELWIN H. T. NASH, referring to ceiling heating, particularly with regard to schools, thought the problem had not been faced on a scientific basis until quite recently. He was Chairman of a committee dealing with the matter, and some research had been carried out on it which would be published shortly and which

bore out precisely what had been said that evening with regard to Liverpool Cathedral.

Two schools with ceiling heating were taken. In one research was carried out and the figures showed a temperature difference of about 1.5° as between any two parts of the room. That showed that, as compared with convection heating by ordinary so-called radiators, the method of ceiling heating had immense advantages. The teachers said that at a temperature of 55° to 57° they were more comfortable than they would be in other cases at a temperature of 60° .

In the second school opinion was not quite so emphatic, possibly due to prejudice, because many teachers, like other bodies of people, were rather averse to innovations. There could be no question about it, however; ceiling heating for schools had come to stay. It had immense advantages over wall panel heating, because wherever a wall panel was inserted the same effect as that produced by a fire resulted; those who were nearest to the radiant surface got rather warmer than they wanted to be.

No mechanical troubles such as were feared by the author had been experienced, and where trouble was caused by down-draught currents from the windows it could be overcome, and a uniform temperature provided, by putting a small radiator just beneath the window.

Investigations he had carried out pointed to the fact that for schools, and particularly for the open air type of school, panel heating from the ceiling would be the heating of the future. Figures by one of the authorities showed that panel heating in the ceiling cost roughly 35 per cent. more to instal, but the running costs for fuel were almost exactly 25 per cent. less, so that the one balanced the other. So impressed were they with the advantages of the system that it was being installed in a new open air school now being built in the South of England.

MR. D. BETTS congratulated the author on explaining in simple language what actually happened when one felt comfortable or uncomfortable owing to variations in temperature. Various opinions had been expressed as to why panel heating in the ceiling, or even on the walls, should be more economic in fuel consumption. The real explanation was, especially in the case of panels in ceilings, that there was an almost complete absence of convection. Taking the extreme case of an open air school with convectors round the wall in the form of open pipes or radiators, the whole of the heat was transmitted into the building by the movement of the air, but the larger the openings in the walls the more would the heat escape. On the other hand, if panels were put in the ceilings the warmth would reach the individuals direct from the panels without warming the air to an appreciable extent, and therefore there would be no loss of heat due to the large open parts of the building.

The fact that considerable economy resulted from using panels whether in the walls or ceilings was very well demonstrated in the case of two large buildings in Manchester—the Liver building and the Cunard building. The Liver building was heated by panels in the walls or ceilings. It was 50 per cent. larger than the Cunard building, which was heated by radiators in the ordinary way, yet the cost of heating the two buildings was about the same. The economy was accounted for by the fact that in one case convection carried a good deal of the heat away every time a window or door was opened.

The author seemed to think a drawback to the use of embedded pipes was that there was a tendency to crack the plaster unless the temperature of the water was kept low. It was essential that the temperature should be kept low; if it rose above 130° the effect was uncomfortable. There was no difficulty nowadays in ensuring that the plaster would not crack, even when the panels had a temperature

of 170°. Certain plaster firms gave a definite five years' guarantee that the plaster would not crack if that form of heating were adopted. The second difficulty mentioned by the author with regard to the embedded system was the difficulty of keeping track of the pipes. They did not become stopped up, however, because the same water was used over and over again, so that any difficulty from that cause was negligible. The pipes were put in the Liver building seventeen years ago. Some were recently cut out for small alterations to be made, and the original mill marks on the inside of those pipes were still visible. Another risk from the use of heating panels which the author mentioned was the possibility of damage to ceilings and floors. Dr. Nash's remark as to the temperature gradient between floor and ceiling answered that question. The actual difference of temperature between the air just above the floor and the air just below the ceiling was less than 1½°, and there was no risk of damage to furniture.

Mr. Atkinson spoke of Dr. Ferranti's house, where jacket water from the oil engine was used to heat the panels. Those panels were warmed by pipes cast in the plaster itself, and the object of using the jacket water was to ensure that the same water should circulate over and over again so as to avoid the risk of oxidation or corrosion.

MAJOR P. H. RICHARDSON said that not a word had been said about ventilation, and, as far as he could see, the modern trend in the heating of buildings was to think of heating only, so that a stage might be reached when there would be no air to breathe.

MR. BARKER, in reply, said that the title of his lecture was "Methods of Radiant Heating," so that his paper naturally did not deal with humidity, ventilation and other subjects which had been mentioned.

One speaker asked as to the best method of heating bedrooms. Personally, he confessed he thought the best way was not to heat them. He believed strongly that the colder a room used for sleeping in the more healthy it was, and although he had an elaborate heating apparatus in his own house his bedroom was never heated. He did not see, however, why radiant heating should not be as suitable for bedrooms as for other rooms, and he would certainly adopt it himself if he wished to heat a bedroom.

He agreed with Dr. Margaret Fishenden that one of the reasons for the superior economy of radiant heating was that the heat was better distributed. Another speaker remarked, very truly, that another reason was that if radiant heating were suitably applied it largely cut out convection, especially when the panels were in the ceiling.

He did not agree, from experience in his own house, that ceiling heating was the most comfortable; he thought the most comfortable method was the wall panel.

On the motion of the Chairman a hearty vote of thanks was accorded to Mr. Barker for his paper, and the proceedings then terminated.

MR. P. BLAGG writes:—

The lateness of the hour at Mr. Barker's lecture prevented any discussion on what is perhaps the most important point in connection with panel heating (and the one on which we can have, at present, no information)—Maintenance.

In the hot-water heating installations of the past we have been well content to obtain a life of 50 years. In the case of any installation forming an integral part

of the structure of a building, we may be dealing not with decades but with centuries. Humanity still having failed to produce craftsmen who never make a mistake, never leave a weak spot in their productions, the welded steel coils embedded in concrete must continue to be looked at askance.

Independent panels or coils, accessible for renewal or repair, would appear to be the direction in which we should seek betterment, and I quite agree with the Chairman that these should appear honestly as radiators and not masquerade as oak panelling. If they fulfil their purpose properly they will soon be the subject of that good design which is "the excellence of every art."

I should imagine the gas-fume heated system, an example of which was illustrated, would suffer rapid internal corrosion, quite apart from the temperature difference between the initial room and the final one (from which Mr. Barker said the fan extracted the fumes "practically cold") constituting a high-temperature heated system in the first room, and, in the last, so low a one as to need 100% of walls, floor and ceiling as radiating surface.

NOTES ON BOOKS.

ANIMALS OF LAND AND SEA. By Austin H. Clark. Illustrated. London : Chapman and Hall, Ltd. 15s. net.

Abundant illustrations, 740 in the text and 10 plates, are a first and obvious feature of attraction ; but the good index and carefully written text make the volume one of utility for every library : indeed, we may say that no library should be without a copy.

The author's aim is to demonstrate the connection between "Biology and Human Progress," this being the title of the first chapter, pp. 1 to 14. Other chapters, taken in sequence, are headed "Animal Names," "Human Foods," "Man as Food for Animals," "Man's Place in the Web of Life," and "Man's Chief Competitors, the Insects." We may pause at p. 61 in this last mentioned chapter, as we have been gradually led towards the view that mighty animal power is not so notable in the elephant, the wolf and the tiger as in the multitudinous insects. The next chapter, "More about Insects," tells us of many things, as "ferocious wives," who devour the "insect husband," and insects that damage metals, especially lead.

On p. 256 we are reminded of the extent to which a knowledge of entomology is interlocked with modern medical practice, and it is pointed out that medical research has made the Panama Canal a possibility. The tsetse fly which functions as carrier of trypanosome diseases figures largely in the book ; and on p. 134 we have five portraits of this pest, Figs. 322-326, and five of his maggots, Figs. 346-349, and Fig. 356.

SOME PROBLEMS OF WAGES AND THEIR REGULATION IN GREAT BRITAIN SINCE 1918. By Alan G. B. Fisher. London : P. S. King and Son, Ltd. 12s. 6d. net.

This volume of XVIII + 282 pages gives us a remarkably well indexed and annotated study of certain questions as to wages, mainly problems which have been brought into prominence in consequence of the war.

The author's first chapter, "Wage Regulation During the War," his second chapter, "Position on the 11th November, 1918," and his third chapter, "The Interim Court of Arbitration," 38 pages in all, are not only introductory to the bulk of the book

but they also form a contribution of value to the history of the war. This value is much enhanced by abundant notes, references and the sectional bibliography at the end of the volume.

Dr. Fisher's work may serve to direct attention to the various schemes for regulating wages during peace times; but unexpected difficulties arise, as various aspects of evasion, altered prices with new values for currencies, and unemployment for those who are below a varying grade of efficiency. Economists have put forward six theories as to the nature of wages, and each one of these theories seems to have a strain of incompatibility with any system of regulation by an external law or fiat. The six theories of wages are lucidly set out with comments by Bliss in his *Encyclopedia of Social Reform*, edition of 1897, pp. 1368-1370. The first theory of wages considered is the wage fund theory of Adam Smith as elaborated by Taussig, Ricardo and Mill. Adam Smith's concise mention as "capital available for employing labour," failing only by insufficiency of explanation. Bliss very properly reminds his readers that Adam Smith's original form "is given up to-day by all economists." But we may suggest that the theory as it culminates with Ricardo and Mill is consistent and tenable; moreover Bliss definitely states that the second of his six theories (the "Iron law" of Lassalle), arises out of the wage-fund theory. It may not be going too far to say that the wage-fund theory looms over all the vexed industrial problems of our days.

One undertaking a serious reading of Dr. Fisher's work has no light task, as full "reading" must involve many visits to libraries, to follow on with the references which are given, or to study books listed in the Bibliography, and it goes without saying that the book under notice should have a place in every economic or historical library.

SOCIAL ASPECTS OF THE BUSINESS CYCLE. By Dorothy S. Thomas. London: George Routledge and Sons, Ltd. 10s. 6d.

This volume is important as an economic study by reason of bringing into use modes of investigation which are either new to the subject or have been regrettably neglected by sociologists.

By a business cycle we are to understand a phase of flux which tends to repeat itself in varying aspects of intensity and composition. The author aims at a graphic, symbolic and verbal comparative study of other social fluxes which may be current with or related to the business cycle. Thus the business cycles of Great Britain from 1854 to 1913 come into consideration as a kind of setting or framework, and these are shown as a graphic complex by Chart I. Data for a comparative study are derived from many social aspects, as for example, birth, death, legislation, population and crime.

On p. 46 mention is made of the early attempt of William Ogle to trace numerical correlations between the marriage rate and trade. Charts II to VIII illustrate the author's comparable efforts to establish approximate numerical inter-relations in other aspects as mentioned above. Chart IX is called a "method chart," and it introduces an Appendix on methods, that most to the front being an adaptation of Poynting's system of estimating "Moving Averages." The author also makes use of the Law of Least Squares, as put forth by Cotes, and adopted by Laplace in his *Theory of Probabilities*.

The author is to be congratulated on having indicated procedures which may guide us in tracing tendencies, and which should ultimately lead to the establishment of important generalised facts.

MEETINGS OF THE SOCIETY.

ORDINARY MEETINGS.

Wednesday evenings at 8 o'clock (except where otherwise stated).

FEBRUARY 29.—ARCHIBALD CRAWFORD, K.C., Director of the Economic League "Industry Fifty Years Hence." THE RT. HON. G. N. BARNES, P.C., C.H., Member of the Council of the Society, will preside.

MARCH 7 (at 8.30 p.m.).—J. H. JEANS, M.A., D.Sc., F.R.S., Secretary of the Royal Society, "Some Wider Problems of Cosmogony." (Trueman Wood Lecture.) SIR FRANK WATSON DYSON, K.B.E., LL.D., D.Sc., F.R.S., Astronomer Royal will preside.

MARCH 14.—HAROLD G. BROWN, M.I.E.E., of the D.P. Battery Co., Ltd., "The Lead Acid Cell: its place in Modern Industry." WILLIAM McCLELLAND, Esq., C.B., O.B.E., M.I.E.E., Director, Electrical Engineering Department, Admiralty, will preside.

MARCH 21.—LIEUT.-COMMANDER R. T. GOULD, R.N. (Retd.), "The Modern Typewriter and its Probable Future Development." COL. SIR HENRY LYONS, D.Sc., F.R.S., will preside.

APRIL 18.—ALFRED C. BOSSOM, F.R.I.B.A., "American Architecture." PROFESSOR A. E. RICHARDSON, F.R.I.B.A., will preside.

MAY 2.—WILLIAM TAYLOR, of Messrs. Taylor, Taylor, and Hobson, "The Standardisation of Scientific Apparatus, with special reference to Teaching."

Date to be hereafter announced :—

CAPTAIN SIR BEACHCROFT TOWSE, V.C., K.C.V.O., C.B.E., "The Education of the Blind."

INDIAN SECTION.

Friday afternoons, at 4.30 o'clock.

MARCH 9.—LIEUT.-COLONEL I. A. E. EDWARDS, C.M.G., Deputy Director, Air Transport, Department of Civil Aviation, Air Ministry, "The Future Prospects of Civil Aviation in India." COLONEL THE MASTER OF SEMPILL will preside.

Date to be hereafter announced :—

SIR JAMES MACKENNA, C.I.E., "The Sugar Industry in India, Java and Mauritius."

DOMINIONS AND COLONIES SECTION.

Tuesday afternoons at 4.30 o'clock.

FEBRUARY 28.—SIR STEPHEN MONTAGU BURROWS, C.I.E. (late Ceylon Civil Service), "The Ancient Civilisation of Ceylon." EDWARD BRUCE ALEXANDER Esq., C.M.G., will preside.

MAY 22.—CAPTAIN SIR CECIL ARMITAGE, K.B.E., C.M.G., D.S.O., "Gambia" (illustrated by lantern slides).

Date to be hereafter announced :—

COL. H. W. CROSTHWAITE, C.I.E., C.M.G., R.E., "Aerial Photography as applied to Survey."

CANTOR LECTURES

Monday evenings, at 8 o'clock.

H. GOUGH, M.B.E., B.Sc., "Fatigue Phenomena, with special reference to Single Crystals." Three Lectures. February 13, 20 and 27.

The syllabus was published in the *Journal* dated January 27th.

DR. MANN LECTURES.

A. G. HUNTLEY, May Construction Company, Ltd., "Applied Architectural Acoustics." Three lectures. April 16, 23 and 30.

The syllabus was published in the *Journal* dated January 27th.

MEETINGS OF OTHER SOCIETIES
DURING THE ENSUING WEEK.

MONDAY, FEBRUARY 27. Actuaries, Institute of, Staple Inn Hall, W.C. 5 p.m. Mr. C. F. Warren, "Further Notes on an Investigation into the Mortality experienced by Pensioners of the Staffs of Banks and Insurance Companies."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Prince D. S. Mirsky, "The Russian Novel after 1880." (Lecture VII.)

At King's College, Strand, W.C. 5.30 p.m. The Rev. C. F. Rogers, "Ecclesiastical Music." (Lecture III.)

At University College, Gower Street, W.C. 2 p.m. Señor Antonio R. Pastor, "The Realistic Epic of Castile."

5 p.m. Dr. A. S. Parkes, "The Internal Secretions of the Gonads." (Lecture V.)
5.30 p.m. Dr. E. A. Baker, "George Meredith." (Lecture III.)

TUESDAY, FEBRUARY 28. Anthropological Institute, 52, Upper Bedford Place, W.C. Mr. E. K. Trautman, "Aveline's Hole, a late Upper Palaeolithic Station in Somerset."

Illuminating Engineering Society, at 15, Savoy Street, W.C. 5.30 p.m. Mr. W. E. Bush, "The Activities of the E.L.M.A. Lighting Service Bureau."

Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. C. H. Oakden, "The Photographic Work of the Rev. J. H. Reade."

Petroleum Technologists, Institution of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 8.30 p.m. Prof. Dr. R. V. Wheeler and Dr. G. B. Maxwell, "Film—characteristics of Pinkish and Non-Pinkish Films."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Sir Bernard Pares, "Russian History from Peter the Great to 1861." (Lecture VI.)

At King's College, Strand, W.C. 5 p.m. Dr. J. A. Hewitt, "Integration in the Nervous System." (Lecture VII.)

At University College, Gower Street, W.C. 5.30 p.m. Prof. Dr. J. G. Robertson, "Hensick Ibsen." (Lecture I.)

8.15 p.m. Miss E. Jeffries Davis, "More London Place-Names." (Lecture IV.)

WEDNESDAY, FEBRUARY 29. British Academy, Burlington House, W. 5 p.m. Prof. H. W. Garrod, "William Collins." (Annual Warton Lecture.)

Public Health, Royal Institute of, 37, Russell Square, W.C. 4.30 p.m. Sir Robert Armstrong-Jones, "The present Legal Aspect of the Treatment of the Insane and Mentally Defective."

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Prof. J. S. Huxley, "The Behaviour of Animals." (Lecture II.)

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Mr. R. F. Young, "Comenius in England."

At the School of Oriental Studies, Finsbury Circus, E.C. 5.15 p.m. Prof. Sir Thomas Arnold, "Islam in Fiction."

At University College, Gower Street, W.C. 6 p.m. Prof. Dr. A. L. Bowley, "Measurement by Index Numbers—Theory and Application to recent Economic History." (Lecture V.)

THURSDAY, MARCH 1. Aeronautical Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 6.30 p.m. Wing-Commander R. M. Hill, "Experiences with the Baghdad Air Mail."

Chemical Society, Burlington House, W. 8 p.m. Mr. F. G. Mann, "The Complex Salts of Divalent Platinum with α -Hy-Triaminopropane."

Chemical Industry, Society of, at Bristol. Annual General Meeting of Bristol Section.
Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m.

Linnean Society, Burlington House, W. 5 p.m.
L.C.C. The Geffrye Museum, Kingsland Road, E. 7.30 p.m. Mr. J. Sevmour Lindsey, "The Artistry of the Domestic Smith."

Metals, Institute of, at the Engineers' Club, Waterloo Street, Birmingham, 7 p.m. Prof. Dr. C. A. Edwards, "Gases in Metals."

Royal Society, Burlington House, W. 4.30 p.m.

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Prof. F. L. Griffith, "Nubia in Antiquity and in the Middle Ages."

University of London, at Bedford College for Women Regent's Park, N.W. 5.15 p.m. Mr. Geoffrey T. Shaw, "Some Tendencies in Modern Music, particularly British."

At the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. V. Tchitchovskiy, "Social and Economic Conditions in Modern Bulgaria." (Lecture IV.)

At the London School of Economics, Houghton Street, W.C. 5 p.m. Major Gordon Macready, "Colonial Defence."

At University College, Gower Street, W.C. 5.15 p.m. Prof. J. E. G. de Montmorency, "Customary Law in the British Empire, Asia and the Pacific." (Lecture VI.)

5.30 p.m. Prof. E. W. Tristram, "English Mediaeval Painting." (Lecture II.)

Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Mr. H. L. Wellington, "Crome and Constable."

Wireless Technology, Institute of, at the Engineers' Club, Coventry Street, W. 7 p.m. Mr. W. H. B. de M. Leathes, "Experiments with Multi-Feed Aerials."

FRIDAY, MARCH 2. Chemical Industry, Society of, at Milton Hall, Deansgate, Manchester. 7.30 p.m. Dr. T. Callan and Mr. S. Horobin, "Some Industrial Applications of the Potentiometric and Conductometric Method of Analysis."

Geologists' Association, at University College, Gower Street, W.C. 7.30 p.m. Prof. E. J. Garwood, "River Meanders."

Philological Society, at University College, Gower Street, W.C. 8 p.m. Mr. L. C. Wharton, "Universal Language of late Dr. Mason." Report of the Copenhagen Conference on Transcription and Transliteration."

Photographic Society, 35, Russell Square, W.C. 7 p.m. Annual General Meeting of the Pictorial Group.

Royal Institution, 21, Albemarle Street, W. 9 p.m. Sir Farquhar Buzzard, "The Psychology of the Sick."

Transport, Institute of, at Leeds. Mr. Raymond Carmichael, "Safety and Speed on Railways."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Mr. Julian Krzyzanowski, "Polish Literature." (Lecture VI.)

At King's College, Strand, W.C. 5.30 p.m. Mr. Stephen Gasalee, "Greek Culture in Egypt at the time of the Arab Invasion."

At University College, Gower Street, W.C. 5 p.m. Mr. C. F. A. Pantin, "Comparative Physiology." (Lecture VIII.)

SATURDAY, MARCH 3. L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Mr. J. E. S. Dallas, "A Naturalist at Land's End."

Royal Institution, 21, Albemarle Street, W. 3 p.m. Mr. Campbell Dodgson, "The Life and Work of Albrecht Dürer." (Lecture II.)

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.(2.)

NOTICES.

NEXT WEEK.

WEDNESDAY, MARCH 7th, at 8.30 p.m. (Trueman Wood Lecture). J. H. JEANS, M.A., D.Sc., LL.D., F.R.S., Secretary of the Royal Society, "Some Wider Problems of Cosmogony." SIR FRANK WATSON DYSON, K.B.E., LL.D. D.Sc., F.R.S., Astronomer Royal, will preside.

FRIDAY, MARCH 9th, at 4.30 p.m. (Indian Section). LIEUT.-COL. I. A. E. EDWARDS, C.M.G., Chief Technical Adviser, Department of Civil Aviation, Air Ministry, "The Air Routes of India." COL. THE MASTER OF SEMPILL will preside.

Tea will be served in the library from 4 p.m.

THIRTEENTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 22nd, 1928. LIEUT.-COL. SIR ARNOLD TALBOT WILSON, K.C.I.E., C.S.I., C.M.G., D.S.O., in the Chair.

A paper entitled "The Excavations at Ur from 1919 to 1926," was read by DR. H. R. HALL, M.A., D.Litt., F.B.A., F.S.A., Keeper of the Department of Egyptian and Assyrian Antiquities, British Museum. The paper and discussion will be published in the *Journal* dated April 20th.

CANTOR LECTURES.

MONDAY, FEBRUARY 27th, 1928. DR. HERBERT JOHN GOUGH, M.B.E., B.Sc., Ph.D., Engineering Department, National Physical Laboratory, delivered the last of his course of three lectures on "Fatigue Phenomena, with special reference to Single Crystals." On the motion of the Chairman, Mr. W. H. PATCHELL, Past President of Mechanical Engineers, a vote of thanks was accorded to Dr. Gough for his interesting and instructive course.

The lectures will be published in the *Journal* during the summer recess.

PROCEEDINGS OF THE SOCIETY.

INDIAN SECTION.

FRIDAY, JANUARY 20th, 1928.

SIR GEOFFREY CLARKE, C.S.I., O.B.E.,

late Director-General, Posts and Telegraphs, Government of India, in the Chair.

THE CHAIRMAN, in introducing the lecturer, said Mr. Maurice Simpson, the Director-in-Chief of the Indo-European Telegraph Department, was giving a lecture on the subject of his own Department, with which he was naturally very familiar. The question of telegraphy was very much before the public at present; the newspapers were full of discussions as to the merits and demerits of both wireless and wire telegraphy, and though this was rather outside the immediate subject of the paper, it was a question so important that it could not altogether be kept outside the discussion. The Indo-European Telegraph Department had carried on for about 70 years the most remarkable work in Persia, and the fact that it had overcome extraordinary physical and political difficulties, and had worked in the most perfect sympathy with the Persian Government, was one of the greatest possible tributes to its organisation and efficiency.

The following paper was then read :—

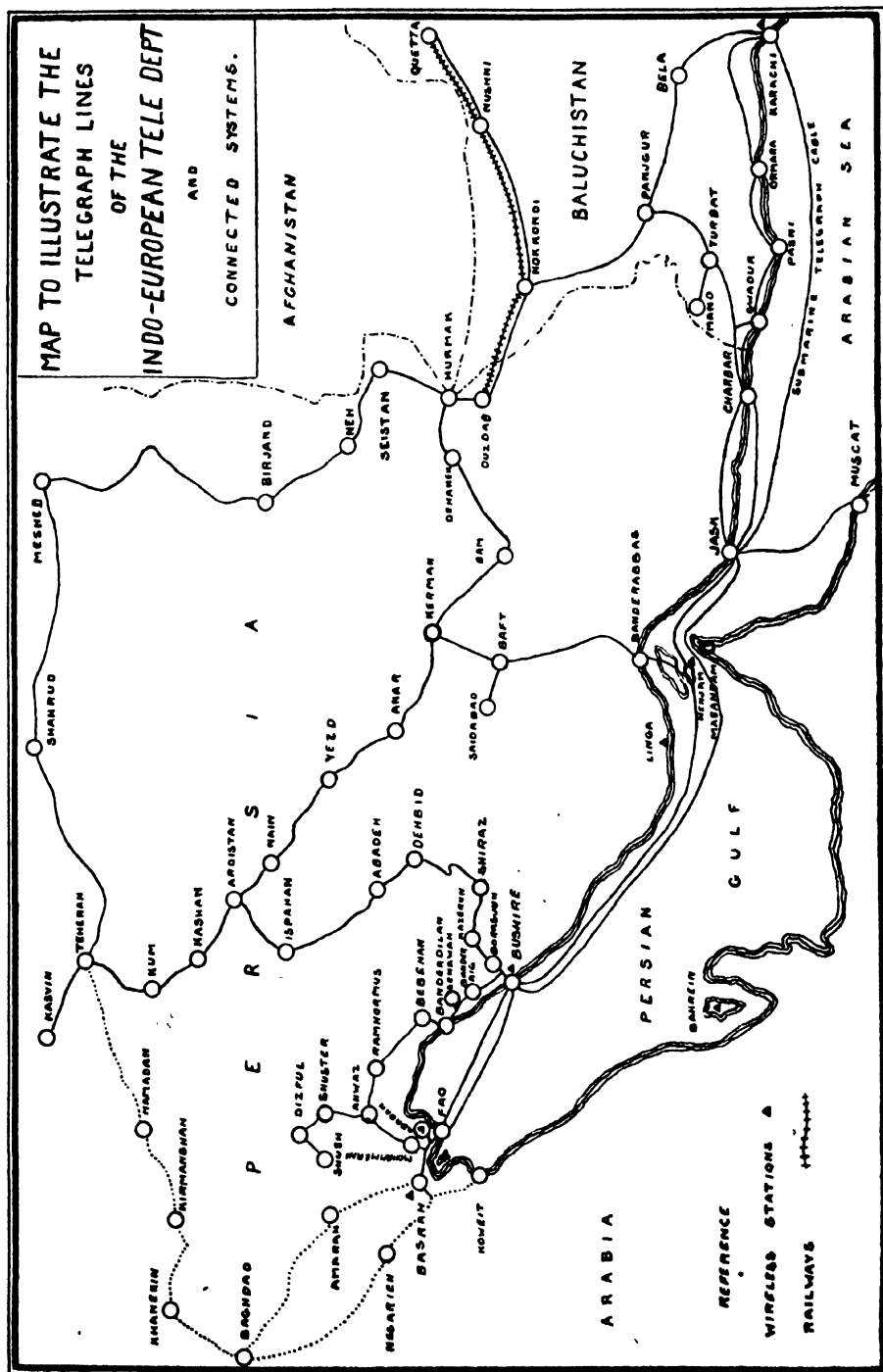
THE INDO-EUROPEAN TELEGRAPH DEPARTMENT.

By MAURICE G. SIMPSON, M.I.E.E.,

Director-in-Chief, Indo-European Telegraph Department.

The Indo-European Telegraph Department is a department of the Government of India about which very little is generally known, the reason being partly because its executive operations are almost entirely outside India, in the Persian Gulf and Persia, and partly because it is in the anomalous position of being the only Department of the Government of India with its headquarters in London and administered directly by the Secretary of State for India. How this anomalous position arose, the necessity for its continuance and the administrative difficulties it involves will, I hope, be made clear as we proceed.

Telegraph lines began to be built in 1840 in England, and in 1852 in India, and in both countries they very rapidly extended. There were early visions of a telegraphic connection between England and India, but it is not till 1856 that we find the first mention of negotiations between England and Turkey for the construction for this purpose of a line eastward from Constantinople towards the Persian Gulf. The European and Indian Junction Telegraph Company were then endeavouring to obtain a concession in Constantinople for the construction of a land line to Kurna at the junction of the Tigris and Euphrates. In 1857 the grant of this concession was definitely refused by the Turkish Government, who undertook themselves to construct the line, but expressed a willingness



to employ British engineers in carrying out the operation. In pursuance of the scheme the Turkish Government applied for and obtained the services of Lieut.-Col. Biddulph, of the Royal Artillery, who, after preliminary arrangements, was able to commence the actual work of erection in August, 1859. He, however, finding work under the Ottoman administration presented too many difficulties, retired from the project the following year, but left behind him a Mr. Carthew and two brothers named MacCallum, all three retired non-commissioned officers of Artillery, to carry on the construction, which they did in the face of innumerable difficulties, with the result that the whole line from Constantinople to Baghdad was completed in 1861. The question then arose whether the route thence to the eastward should be direct to the head of the Persian Gulf, on which section interference by the Arab tribes was to be feared, or should be via the Persian frontier at Khanikin to Teheran and thence via Ispahan and Shiraz to Bushire. Eventually Turkey was persuaded to construct both routes and in 1863 work was commenced, the line from Baghdad to Khanikin being completed in October, 1864, and that to Fao in January, 1865.

In the meantime there had been considerable activity on the Indian side. During the year 1861 the Government of India instructed Colonel Patrick Stewart, a brilliant young officer of the Royal Engineers and the pioneer of the Indo-European Telegraph Department, to make a survey of the Mekhran coast and of the Persian Gulf. In the following year he was able to lay before the Secretary of State a definite scheme, in which he recommended that a land line should be constructed from Karachi westward as far as Gwadar, and that a series of cables should be laid thence to Fao at the head of the Persian Gulf. He very shortly afterwards added a recommendation that the cables should be extended from Gwadar to Karachi, thus duplicating communication over this section where, it was feared, the cable might be exposed to damage from the heavy seas of the south-west monsoon.

It is difficult now to realise the boldness of these proposals at a time when confidence in submarine cables had been badly shaken by the failure two years before of a cable laid in the Red Sea as part of a cable route to India, but it was believed that the causes of the failure were well understood and could be avoided, and Col. Stewart's project received the support of the most eminent electricians of the day, among whom was Prof. William Thomson, afterwards Lord Kelvin. The scheme was approved and Col. Stewart was ordered to carry it out. The cable was manufactured at Messrs. Henley's Telegraph Works at Woolwich, and its manufacture and submersion was under the control of Messrs. Bright and Clark, well-known telegraph engineers. It was sent out in five sailing ships to Bombay, whence the ships were towed by steamers of the Indian Navy to Karachi and up the Gulf and the cables were laid in the sea without any serious accident. The section Gwadar to Mussendom was completed in February, Mussendom to Bushire in March, Bushire to Fao in April

and Gwadar to Karachi in May, 1864, thus completing the connection between Karachi and Fao in readiness for the Turkish line on to Constantinople, which was completed some months later in January, 1865.

Before this Mr. Walton of the Indian Telegraph Department had been deputed to construct the land line from Karachi to Gwadar; he commenced the work in June, 1862, and completed it the following April. In constructing this 400 miles of line Mr. Walton encountered very great hindrances, not only because of the utterly barren and inhospitable nature of the country with the consequent lack of water and difficulties of transport, but also from the jealousies, bickerings and opposition of the local petty Chiefs, and that he was able to construct it at all is a testimony to Mr. Walton's perseverance and ability.

It has been stated above that the Turkish line from Baghdad to Khanikin on the Persian frontier was completed in October, 1864. The line from Khanikin to Teheran and thence south to Bushire was constructed on behalf of Persia by British Engineers under Major Champain, an officer of the Royal Engineers; it was commenced in 1863 and was completed in October, 1864, but the line was so continuously interrupted that it was never really opened, and in fact, the Baghdad to Teheran section has never been used for international telegraph traffic with India.

The first telegraphic communication between Europe and India was effected on the completion of the Baghdad Fao section of the Turkish line on January 27th, 1865, just 63 years ago. It is pathetic to recall that Col. Patrick Stewart, to whose energy, perseverance and remarkable abilities the success of the project was mainly due, died at the early age of 33, in Constantinople, on the 16th January, 1865, a few days only before the completion of the connection between Europe and India for which he had worked so strenuously.

In the month after the opening the number of messages exchanged was 62 only, but this number quickly increased, and in the December following 2,365 messages were exchanged, the charge for a telegram being £5 for 20 words or part of 20 words, while the average time of transit was 6 days 8 hours and 44 minutes. At this time a letter to Bombay took just over a month on the way, being carried by sea to Alexandria, across Egypt to Suez, and thence by sea to Bombay. In the same year efforts were made to transmit messages via the Russian lines, which had been extended through Tiflis to Teheran, but the service was found to be most indifferent, the average time of transit being 17 days 5 hours and 5 minutes, while messages were so badly mutilated as to be unintelligible.

The delays to messages between England and India was the subject of universal complaint; a Parliamentary Select Committee on "East India Communications, including Telegraphs," sat and took evidence in 1866, and various proposals were made for the improvement of the telegraph service; alternative schemes were submitted and diplomatic representations made, but

the difficulty was first solved by Messrs. Siemens and Company who offered to construct an independent double line of telegraph from London to Teheran, provided that Her Majesty's Government gave them adequate support. They received this support, and Messrs. Siemens of London and Messrs. Siemens and Halske of Berlin were able to obtain the necessary concessions from Germany, Russia and Persia. An English company called the Indo-European Telegraph Company was formed to take over the concessions and work them, with the result that the combined Indo-European route, with the section London to Teheran worked by the Indo-European Telegraph Company, and the further section Teheran to Karachi via Bushire worked by the Indo-European Telegraph Department of the Government of India, was opened for traffic on January 31st, 1870. The average speed of messages was immediately increased, and we find in the year 1871 the average transit time by the Turkish route was 1 day 6 hours and 20 minutes and by the Indo route only 6 hours and 7 minutes.

When the Indo Company's line from England to Teheran appeared likely to mature it was anticipated that the new telegraph route to India would be largely patronised by the public, and that a line worked by English telegraph clerks throughout would, by greatly reducing delays and errors, cause a corresponding increase in the number of messages forwarded. To meet this expected increase in traffic it was necessary to duplicate the line from Teheran to Karachi. Up to this time the departmental system consisted of one international wire from Teheran to Bushire, one cable from Bushire to Gwador, and one cable and one land line from Gwador to Karachi. After much negotiation with Persia and the local Chiefs the land line was extended from Gwador to Jask in 1869, and in the same year a new cable was laid from Jask to Bushire, the first cable having in the previous year been moved from Mussendom to Jask for climatic reasons. It was not however found possible to add another wire for international use on the section Teheran to Bushire until the year 1874. Thus, when the Indo route was opened for traffic in January, 1870, there were two wires from London to Teheran, a single wire Teheran to Bushire and a duplicate line of cables and land lines thence to Karachi.

In the meantime submarine telegraphy had made enormous strides, thanks chiefly to the genius of Lord Kelvin and the far-seeing enterprise of its commercial pioneers, amongst the foremost of whom was the late Sir John Pender. Under his auspices the British-Indian Submarine Telegraph Company, soon afterwards known as the Eastern Telegraph Company, completed a cable route from England to Bombay in 1870, a few months only after the completion of the Indo overland route.

Thus, in 1871 the three telegraph routes between England and India, the Turkish via Constantinople, the Indo-European via Germany, Russia and Persia, and the Eastern cable route to Bombay, were all in operation, and so continued, with of course occasional interruptions to the one or the other, till the outbreak of war in 1914.

We must now turn to the agreements which have been made with Persia under which the Department has erected and worked its telegraph lines in that land. The first convention was made in 1863, and by it the idea of the British erecting and working a line in Persia was entirely set aside. On the other hand Persia undertook, on our providing the material at Persia's expense, to make and work a line for herself from Khanikin to Bushire and to allow us, at a tariff to be fixed afterwards, to transmit our Indian messages by its means. The only intervention on our part provided for by the convention was the presence of one English officer for a limited period in Persia to advise as to the best method of construction. Unpromising as such a convention was, it was decided to take action on it in the hope that something more practical might be evolved. Major Murdoch Smith of the Royal Engineers, with a staff of three officers and twelve non-commissioned officers of the same corps and six civilians, was sent out to construct the line. Their arrival in the country was not unnaturally viewed with the very strongest suspicion, and the whole country from the Shah downwards regarded them as most unwelcome guests. It would be an endless undertaking to attempt to describe the difficulties by which their task was surrounded. Success often seemed well-nigh hopeless, but, thanks to the tact and the zealous and loyal efforts of the widely-scattered staff, suspicion gradually gave way to trust and enmity to friendship. The position, which was a very unsatisfactory one, was much improved by a convention made in 1865, under which a second wire was to be erected, the materials being provided as before at the cost of Persia, but now the erection was to be in charge of a British engineer and staff paid for from British funds. It was also stipulated that a British staff should be engaged to organise the working of the line and to give instructions to the Persians in telegraphy. At the end of five years this British staff was to be withdrawn and the line handed over to Persia. The second wire was to be used solely for international messages sent in European language. It was under this convention that the Department was working the Bushire-Teheran line when the Indo route was opened in 1870, but the single international wire which it contemplated was soon found to be inadequate to cope with the traffic and a further convention was entered into in 1872 for the erection of another wire. This latter convention was to remain in force up to 1895, but it has been from time to time extended, and, as now agreed, it will remain in force up to 1st January, 1945. Under it the line from Teheran to Bushire which was erected partly at the cost of Persia who paid for the material and partly at the cost of India who paid the salaries of the British establishment and other expenses, was to be maintained wholly at the charge of British or rather Indian revenues. One wire is given over entirely to Persia for working local traffic, that is, messages originating in one station in Persia and terminating at another, the two remaining wires being worked by the Department for international traffic. A certain amount of local traffic is also carried on these two international wires, but the revenue derived from it is handed over to Persia.

Receipts for international traffic originating or terminating in Persia are shared between Persia and the Department, Persia receiving the larger share, while for international messages passing through Persia a fixed royalty is paid to the Persian Government. For a comparatively small initial outlay, therefore, Persia is in possession of an efficient telegraph line just over 700 miles in length, maintained entirely free of expense to her and from which she derives all the revenue accruing from local traffic and a very considerable share of the revenue from international traffic. On the other hand India has, so long as the convention lasts, control of an essential link in the Indo route from England to India.

The Gwadar-Jask line which runs through Persian territory was erected under a convention concluded in 1868 permitting the British Government to erect and work the line at their own expense in return for an annual payment of Tomans 3,000, equal to-day to about £600. This convention will also expire on January 1st, 1945.

Telegraphic communication between the British Minister at Teheran and the Consul General at Mashad is afforded by the Persian line between those two places, but it proved so inefficient that in 1885 by agreement with the Shah the maintenance of the line was undertaken by the Department. India agreed to contribute Rs. 20,000 a year towards the cost of maintenance, but this sum, together with such sums as Persia contributed, was quite inadequate to do more than patch up the line, which was in a deplorable condition. In 1892 special grants were made by Persia and India and the late Mr. King-Wood was deputed to put the line in order, since which time it has proved efficient. The cost of maintenance is shared between Persian and Indian revenues. The line is worked by the Persians but the Department has the use of it for a short time daily for the transmission of state telegrams. The line from Mashad south to Seistan was before the war under the control of Russia.

Towards the end of the century the increase of traffic pointed to the need of an alternative line between Teheran and Karachi, and after considerable negotiation a convention was signed with Persia in 1901 for the construction of a three wire line from Teheran through Yazd and Kerman to the Perso-Baluch frontier at Hurmak, to meet there a line constructed by the Indian Telegraph Department from Quetta. The line, which was constructed by the late Mr. King-Wood, was completed in 1907, and, a branch line from Nok Kundi on the Hurmak-Quetta line having also been completed to Karachi the same year, the desired alternative route became available for traffic.

By the terms of the convention this Central Persia line was constructed by the Department, the Government of India treating the cost as an advance to Persia. One wire is made over to Persia for local traffic and the other two are worked by the Department, mainly for international traffic. As in the case of the Teheran-Bushire line Persia receives all the receipts accruing from local traffic and a major share of the terminal rate on international traffic originating

or terminating in Persia, but has leased the revenue from international transit messages to the Department in exchange for an annual rental of 4% of the capital cost of the line. Thus Persia obtained without any cost to herself a thoroughly good telegraph line almost 800 miles in length, passing right through the centre of her country, one wire of which is entirely for her own use for local internal traffic.

There was one further work undertaken by the Department in Persia before the war, and that was the reconstruction of the lines in Arabistan; the lines running westwards from Bushire to Mohammerah, Shuster and Dizful. These lines had fallen into such disrepair as to be practically unworkable, and an agreement was made in 1913 under which the British Government advanced the money needed for their complete reconstruction, in return for which Persia agreed to a renewal up to 1st January, 1945, of (a) the convention of 1868 for the Gwador-Jask line, (b) the convention of 1872 for the Teheran-Bushire line, and (c) the convention of 1901 for the Central Persia line.

Let us now turn to a consideration of the administration of the Department. Its first head was Col. Patrick Stewart, who seems to have had no fixed headquarters, but to have spent his time in the Persian Gulf, in Persia and Constantinople, with visits to India and London. He was nominally under the Government of Bombay, whence he derived his funds, but he appears to have corresponded direct with the Secretary of State and the Government of India impartially. On his death in January, 1865, Major Champain, who, it will be remembered, was in charge of the operations in Persia, was nominated by the Secretary of State to perform the duties of Director-in-Chief. Col. Goldsmid of the Madras Staff Corps, however, who had previously been engaged on the inspection of the lines in Turkish territory and was with Col. Stewart in Constantinople when the latter died, also received orders, apparently from the Government of India, to consummate the Col. Stewart's work. The confusion lasted about six months, when Col. Goldsmid was definitely appointed Director-in-Chief with Major Champain as his assistant.

There was an office in London where the general administration was conducted, an office in Constantinople under a Commissioner, while the Persian and Persian Gulf sections were under Directors with headquarters at Teheran and Karachi respectively, the whole being under the Government of Bombay. Remembering the difficulties in communications in those days, the organisation of such a scattered department must have been an onerous task, and it was further complicated by the many delicate questions which arose both at Constantinople and Teheran requiring diplomatic action. Col. Goldsmid was for ever on the move from London to Bombay, Karachi, Teheran and Constantinople as circumstances required, but by 1870 he felt that the position had become sufficiently stabilised to enable him to recommend the abolition of the appointment of Assistant Director-in-Chief, proposing that he himself should retire and Major Champain should become Director-in-Chief, which was agreed

to. Very soon after Champain's appointment the question of his headquarters arose, the Government of India proposing that these should be at Bombay. Major Champain, however, vigorously opposed this proposal; he pointed out that the interests of the line were intimately bound up with those of the Indo-European Telegraph Company, in conjunction with whom our traffic was carried, that he had constantly to consider questions that affected the Company and the Department alike, and that he had much correspondence with other telegraph administrations which could not be conducted from India without serious inconvenience and loss of time. He also referred to the difficult questions which arose with Persia in relation to our treaties, which had to be dealt with in communication with the Foreign Office. The principal traffic office must necessarily be in London, where cash was received for every message sent to India and the accounts made out for the shares due to other administrations. These arguments prevailed and the headquarters of the Department were fixed in London, but the control of the Department was shifted from the Government of Bombay to the Public Works Department of the Government of India.

Sir John Bateman Champain, as he afterwards became, held charge of the Department till his death early in 1887, when he was succeeded by Col. Murdoch Smith, the Director of the Persian section. The question of the future administration of the Department was again taken up, and although the arguments that Col. Champain had advanced in 1871 had lost none of their force they were now disregarded, and, in the hopes of effecting some small economy, it was decided to abolish the appointment of Director-in-Chief and transfer the Department to the charge of the Director-General of the Indian Telegraph Department. This was carried out early in 1888 when Col. Murdoch Smith retired, but it did not prove successful. Col. Mallock, the Director-General of the Indian Telegraph Department, travelled over the whole system from Karachi to Teheran, and in 1890 submitted an exhaustive report to the Government of India, in which he strongly advocated the resuscitation of the appointment of Director-in-Chief in London. He pointed out that the addition of the Indo-European Department placed an intolerable burden on the Director-General in India, who had already a very large and responsible charge, and he showed the necessity for the head of the Indo-European Department to be in London, where he could be in close communication with the commercial cable companies with whom the interests of the Department were inextricably bound. His recommendations were accepted, and in June, 1893, the control of the Department was transferred from the Government of India to the Secretary of State and Mr. Ffinch, the director of the Persian Gulf section, was appointed Director-in-Chief with headquarters in London. This organisation has continued down to the present time, Mr. Ffinch being followed by Sir Henry Kirk and Sir Rayner Barker, whom I had the honour of succeeding about three-and-a-half years ago. It is still the case that the successful working of the Department

is dependent on close co-operation between the Director-in-Chief and the cable companies in London and on the successful solution, through the Foreign office, of questions arising in relation to our agreements with Persia, and in my opinion the existing organisation is the most suitable to meet the peculiar conditions of the case. The Staff under the Director-in-Chief consists of the Directors of the Persian Gulf and Persian Sections with their headquarters at Karachi and Teheran respectively, 27 gazetted officers and 47 General Service Clerks approximately equally divided between the two sections, 115 Persian Gulf Signallers in the Gulf Section and 58 Persian Section Signallers in the Persian Section. The gazetted officers with one or two exceptions are entirely recruited by promotion from the grade of General Service Clerk. The latter have been recruited as telegraph clerks mainly from England, for, although the experiment was tried, it was found that the conditions in Persia were unsuitable for Anglo-Indians or Indians. The staff serving in Persia have been subjected to conditions of existence very different from those affecting their colleagues in most other countries. Repairing the lines and keeping as close as possible on the heels of Afghan gun runners who were wrecking them, and this in midsummer in the desolate no man's land near the Afghan frontier is no child's play ; nor is rebuilding a mile of line completely washed away in the Lut desert. In such circumstances it is the case of one Englishman alone with a handful of Persian labourers, drinking brackish water till he can hardly swallow, eating anything that comes his way and sleeping on the ground. The safety of our offices and staff has in many cases undoubtedly been due to the reputation which by their own conduct our officers had established. Many of them have been robbed by brigands and left almost or quite naked to struggle to the nearest village, while others less fortunate have been murdered. The winter cold of the wind-swept plateaux is intense and so is the heat in summer in the lower lying plains and deserts. It is difficult to convey an idea of the amount of suffering and hardship that the staff have endured ; there is hardly a senior member who has not been through famines, epidemics, riots and other excitements in plenty. If life in the Gulf Section is not beset in the same way with alarms and excursions, it must not be forgotten that many of the staff in that Section serve in isolated coast stations and in desolate islands in what is perhaps one of the worst climates in the world. The staff have served the Government of India with unswerving loyalty in trying, difficult and not infrequently dangerous circumstances, and in regions so remote that, in the absence of any special incident, their steady and valuable work is often in danger of passing unnoticed.

The construction of the departmental telegraph system and the general organisation of the staff have now been considered, but these exist solely for the purpose of the efficient transmission of telegrams, and it is to this aspect of the matter we must now turn. The Indo-European Telegraph Department had, so far as its lines extended, the monopoly of traffic between Europe and the East from the commencement of 1865 to the commencement

of 1870, while the Turkish line was the only route available. The tariff charged for a telegram from England to India was £5 for 20 words or part of 20 words, but this was reduced in 1869 to £2 17s. od., and the average time of transmission was rather over 5 days. In spite of the monopoly and the high charges the Department only showed a small surplus of receipts over working expenses quite insufficient to pay the interest on the capital expenditure of £960,000 that had been incurred. When the Indo-European Telegraph Company in 1870 opened their route to Teheran and the Eastern cable route to Bombay was also established the traffic was divided between the three routes, the charge by each being the same, viz., £2 17s. od. for 20 words. There was not enough traffic to make any one of the three routes remunerative and the Indo-European and Eastern Companies gradually raised their rates till in 1871 the charge was £4 10s. od. for 20 words, Turkey still working at the £2 17s. od. tariff. At this lower rate the Turkish route was able to attract a considerable proportion of the traffic in spite of working at a much lower speed, the average time for a message being about a day and a half as against 6 or 7 hours only by either of the other routes. The two companies then complained that their lines, paid for and maintained by private capital, were being undersold by a line which, supported by state revenues, continued to work at a dead loss. A Sub-Conference met at Berne, and the Turkish administration was induced to raise its rate also to £4 10s. od. At subsequent Telegraph Conferences it was arranged that the tariff by the Turkish route should always be slightly lower than that by the others, but the difference was never again sufficient to attract more than a very small percentage of the traffic. In 1876 the system of charging by the word was introduced, the charge from Europe to India being fixed at Frs. 5.50 per word via Teheran or Suez and Frs. 5.00 via Turkey. From time to time as the traffic increased and advances were made in the science the rates have been reduced and cheaper classes of messages introduced, so that it is now possible to send what is called a 'Daily Letter Telegram' of 20 words for the very modest rate of 4½d. a word.

In 1878 the Eastern Telegraph Company, the Indo-European Telegraph Company and the Indo-European Telegraph Department entered into a working arrangement with a view to the avoidance of the serious fluctuations in receipts caused by the interruption of the one or the other route, and to the attainment of as high a stability of revenue as possible. This co-operation enabled certain other economies to be effected and placed the companies in a position to offer the public a greatly improved service.

From this time onwards to the outbreak of the great war the Department carried a steadily increasing number of messages, thus :—

Year.	No. of Messages.			
1879-80	...	...	...	42,487
1889-90	...	...	...	106,702
1899-00	...	...	...	152,837
1900-10	...	...	...	274,092

At the outbreak of war in August, 1914, the Company's lines through Europe were of course immediately put out of action, and it seemed at first that the Department would have little work to do. Sir Rayner Barker at once saw the danger of Russia being cut off from telegraphic communication with her allies by any of the direct routes to the west, and he realised that the roundabout route via Bombay, Karachi and Teheran might become of vital importance. There were already two routes available between Karachi and Teheran, via Bushire and via the Central Persia line, but a third could be made available via Mashad and Seistan by completing the link between Seistan and Hurmak. An agreement was quickly reached with Persia, who authorised the construction of the line in September, 1914, and it was completed the following month. This alternative line, of which it will be remembered the section Mashad to Seistan was worked by the Russians, proved of invaluable service, especially when enemy activity interrupted the Teheran-Bushire line.

When Turkey entered the war and a campaign in Mesopotamia started it was clear that the single cable between Fao and Bushire was quite inadequate to meet telegraphic requirements. Fortunately a sufficient length of suitable ready-made cable was available in London, and this was purchased and sent out; it escaped attack from the enemy's submarines and was successfully laid in June, 1916. It was also found impossible to maintain the land line between Jask and Charbar, owing to the turbulence of the tribes in the interior, and a short length of cable was laid between these places. Thus the Department was able to provide two comparatively safe lines which carried the whole traffic between Mesopotamia, the Persian Gulf ports and Persia on the one hand, and India, England and all parts of the world on the other. This traffic was extremely heavy, amounting in 1918-19 to 660,000 messages containing over seven million words, in addition to a very large number of messages relating to the sick and wounded which were carried free of charge. The traffic was carried without any serious breakdown or even undue delay, and the Department is, I think, justified in claiming to have rendered a very important service to the campaign in Mesopotamia.

At the end of the war the Indo-European Telegraph Company at once took action to restore their line through Germany, Poland and Russia. A great deal of work was entailed in this restoration, but it was successfully accomplished, and the Indo route was once more established in August, 1923, having been interrupted exactly 9 years. The Department again resumed the work for which it mainly exists, the transmission, in conjunction with the Company, of messages between Great Britain and India and countries beyond. To this is now added the traffic with Iraq which before the war was transmitted via Constantinople, the total number of messages dealt with by the Department in the year ended 31st March last having been just under 400,000.

I cannot conclude this account of the Department without some reference to the "Beam" wireless service recently opened with India, which has proved

very successful and has attracted a considerable share of the available traffic. This new service has only been working for four months, and it is too early to say yet what the outcome may be, but I think it is probable that the cheap rates now available will so stimulate the telegraph habit that the volume of traffic will increase to dimensions which a few years ago would have been thought impossible, and that there will be ample work for all.

DISCUSSION.

THE CHAIRMAN, in opening the discussion, said the meeting had listened with great pleasure to the lecturer's most interesting account of the Indo-European Telegraph Department. Mr. Simpson had referred to the manufacture of a cable in 1865 by Henley's. The core of all cables, of course, consisted of a copper wire covered with a gutta-percha core, surrounded with sheathing wires, and the core of the 1865 cable was manufactured by the Gutta-percha Company, the oldest manufacturing company of cables in the world. That was now the Telegraph Construction and Maintenance Company, of which he had the honour to be one of the managing directors. It was a very wonderful thing to have that enormous line consisting of the two systems of the Indo-European Telegraph Company and the Indo-European Telegraph Department, going right across Europe and across Persia, through trackless deserts and very difficult country, and maintaining in ordinary times a very stable system of communication between Great Britain and India. During the war, undoubtedly, the system had been interrupted for a considerable period, but during that period, as had been pointed out by the lecturer, the Indo-European Telegraph Department had rendered invaluable services for British communications with Mesopotamia; in fact, if it had not been for the telegraph system of the Department, it would have been almost impossible to carry on the campaign in Mesopotamia at all. It might be thought that with the splendid system of cables which existed in England and India, and the new beam wireless waves, there was hardly room to-day for a very long land line; but he looked upon the Indo-European systems as a very important British asset. If those systems were to give up their great land lines, they would undoubtedly be taken over by one of the big European countries and probably worked in competition with the existing British cable system. He considered that the very existence of the Indo-European Company and the Department in Persia was of extreme importance to the British Empire. If those systems were to pass into any foreign hands it would, he thought, be very detrimental to British interests.

The joint purse to which the lecturer had referred was a fine example of industrial association. It was very largely owing to the joint purse that the Indo-European Company and the Department were enabled to revive their systems so extraordinarily well in 1923. During all that long period when their communications were interrupted, if it had not been for the joint purse the Indo-European Company would probably have disappeared, but owing to the joint purse they were able to restore their system, and were now working as well as ever.

The lecturer had touched rather lightly on beam wireless. To all those who dealt with cables, beam wireless was rather a sore subject; but they were not afraid. Beam wireless was a most marvellous invention. It was not necessarily beam wireless, but short-wave wireless and it was a wonderful invention, and had proved very successful; but it had very definite limitations. It was not by any means continuous; almost every day on almost every circuit there were times of

failure, and that, to anyone who had practical experience of a telegraph office, was a very serious matter. Another point about beam wireless was that it was not secret, and it could not be made secret. Anybody could tap it, and it was subject not only to atmospheric interference, but also to deliberate interference by other beam wireless stations. But it had a place, and an undoubted place, in the future, and with the reduction of tariffs we were arriving at a position in which the telegraph would be used very largely to replace the ordinary letter mail; but when cable letters became cheap enough, he thought they would become the ordinary means of communication, and when that extended there would be ample room for both cables and wireless circuits throughout the world. One heard of the very high speed obtained on wireless circuits, but in telegraphy very high speed was often a nuisance unless it could be controlled. To get any single circuit pouring in 2,000 letters a minute was a most harassing matter, because it could not be dealt with; and the importance of the new type of cable, known as the loaded cable, was that one could get the high speed if one wanted it, but one got something that was far more valuable, namely channels. The 2,000 words a minute was divided into channels, each working in a separate circuit, and this got through the traffic at a workable speed, which could be handled by four or five operators. That was better than having the office loaded up with self-recording messages, which would all have to be deciphered afterwards at hand speed, and could not possibly be handled by any single operator.

VICE-ADMIRAL H. W. GRANT, C.B. (Joint Managing Director, Eastern Telegraph Company) said it was a great honour to him to be invited to speak on Mr. Simpson's lecture, and he would like to say a word or two about the Eastern Telegraph Company and its associated Companies. Many people did not know what the Eastern Company was, and he had taken the liberty of bringing a map which looked rather like an advertisement. All the red lines shown on the map were the Eastern Telegraph Company's system.

He wished to congratulate his friend Mr. Maurice Simpson on his excellent lecture. He had never been through the history of the Department before, and was very grateful to Mr. Simpson for his historical survey. It was often a great help in negotiations to realise what had happened in the past. He had only been connected with the Eastern Telegraph Company for about nine years, but it was a most absorbing business. The Company worked in close co-operation with the Indo-European system. Every three months there was a meeting of the Indian Joint Purse Committee, consisting of the Eastern Telegraph Company, the Indo-European Telegraph Company and the Indo-European Telegraph Department, and the business never took more than half an hour. That showed how well a commercial company could work in co-operation with a Government Department.

All those red lines shown on the map, going to all sorts of odd places, linked up a great part of the world. Mr. Simpson had referred to the speed of messages, which, at one time, was six days to India, and people were very pleased when it came down to six hours. To Bombay at the present time the Eastern Company was working—except for a short stretch at Suez, which was going to be altered to underground land lines—without anybody touching the message from London right into Bombay. The button was pressed in London, and the message was in Bombay in a second. That was rather wonderful, and had been brought about by the ingenuity and splendid work of the staff of the Eastern Telegraph Company. The Company had a keen staff, who were always looking out for something better. A few years ago he had been worried because they could not get the "balances"

right. The balances were always troublesome ; a section would get stopped for a few hours, but now the staff had been able to synchronise the speed of the cable all the way through by a system of relays. By means of this system of relays, as the message came into the station it was automatically shot through and given another boost on the line. Another important thing about it was that if there was an error in any signal it was corrected at the succeeding station, and went on correct ; so that if it left London right it must get to Bombay correct.

The time taken telegraphically was, of course, infinitesimal. One of the first sections dealt with in that way was the one between London and Cape Town, and one of the tests applied was to press a button in London, and arrange for a man at the Cape Town end to press another button when he saw the signal come through, and the reply had come back in $1\frac{1}{2}$ seconds. That was practically instantaneous, allowing for the time taken by the man to respond to the signal, which might take half a second.

Before such an audience as that he was tempted to say a few words about the importance of an enterprise which perhaps was not quite fully appreciated. In the war it would have been impossible to carry on without the telegraphs. He had been at the Admiralty as Director of Operations, and the communications received by cable were a very big factor in winning the war. Once a submarine got in near Lisbon, and cut a cable. Another incident which came to his notice was when he had been in command of the fleet which was trying to hunt down the "Emden." The crew of the "Emden" had landed at Cocos and smashed up everything, but luckily the staff had buried all the spare instruments in the sand, and as soon as the enemy went away the staff dug them up and restored communication in a few hours. Then again in the Falkland Island the Pacific cable was cut. Unfortunately the staff, though they had buried the instruments in the sand, put up a placard in the office to say where they were, which was rather silly, and therefore the enemy knew exactly where to find them.

The lecturer had mentioned the number of free messages that were carried. He might add that the Eastern Telegraph Company carried millions of words free for the soldiers of the Empire, and they were only too proud and thankful to be able to do it.

MR. H. L. M. TRITTON (Chairman, Indo-European Telegraph Company, Ltd.,) said Mr. Simpson had truly remarked that his Department was not very much in the public eye, but for all that it filled a role which was very important both from a strategic and from a commercial point of view. The lecturer had referred to the difficulties and dangers which were so successfully surmounted in the early days, and that audience could not but be struck by the indomitable courage of those pioneer officers of the Department. The foundations of that great undertaking were indeed well and truly laid, and the same spirit which animated those pioneers was very evident in their successors to-day. As Chairman of the Indo-European Telegraph Company he wished to emphasise the close working which existed between the Company and the Department, and also the Eastern Company, as Admiral Grant had just explained. As had already been pointed out, since 1870 the Indo-European Telegraph Company had worked in the closest co-operation with the Department, and, as a result, direct communication was obtained between London and Teheran and Teheran and Karachi, and he might add that for about the last twenty years instantaneous communication by means of the Company's and the Department's lines had been achieved over a distance of 5,300 miles between

London and India. After the war, the company of which he had the honour to be Chairman was of course severely handicapped because their line was down in many places, but he was glad to think that the work of reconstruction was expeditiously and satisfactorily carried out under the Chief Engineer of the Company, Captain Cook, and it was again open for through traffic in August, 1923.

To touch on a personal note, he might mention that his father had been a director of the Indo-European Telegraph Company since its inception, and for many years before 1923 had been its Chairman. Although he (the speaker) was a comparative newcomer to the telegraph world, he very much shared the view expressed by the lecturer in the last paragraph of his most interesting paper, that we were on the threshold of great developments and largely increased traffic, and these would, in his opinion, more than fill the different methods of transmission which existed to-day.

LIEUT.-COLONEL SIR ARNOLD T. WILSON, K.C.I.E., C.S.I., C.M.G., D.S.O., remarked that after listening to Mr. Simpson's description of the arrangements of the Indo-European telegraph system, his audience would have come to the conclusion that the Athanasian Creed was a simple formula compared to the Department's arrangements, with its works in one country, its administration in another, and its headquarters in a third; itself a Government department it relied for its communications with the United Kingdom by land on the Indo-European Telegraph Company, which at all events before the war was under Russian protection, though its Chairman was invariably a British subject with his headquarters in London. Financial stability was ensured by the device of a joint purse which it shared with at least one other company, and by half-hour conferences every three months—at which, he hoped, the interests of the public were as carefully safeguarded as those of the companies appeared to have been! It was an interesting, but clearly an exceedingly complicated, state of affairs.

Not much had been said about the Persian Government in the matter, except as the recipients of considerable revenue. The Persian Government was one of the first to enter the International Postal Union. They were also one of the first Governments to adhere to the International Telegraph Conventions, which they could scarcely have done had not the Indo-European Telegraph Department been at their disposal to enable them to carry out the rather complicated arrangements ancillary to international conventions. They had had, ever since the 'seventies, a thoroughly sound system of telegraph communication provided partly by the Company and partly by the Department, covering, as the map showed, all the principal centres of Persia, and which had been of inestimable value. Had those lines been owned and controlled by the Persian Government in early days, they would have been treated perhaps with less respect by the local residents.

He had been in Persia for about 20 years and he believed he knew personally between 1907 and 1920 at least half the general service clerks and the superintendents of the Department, both in the Persian Gulf and in Persia, and he was glad to have the opportunity of expressing his admiration and respect for them. There was no more efficient Government Department in India or out of India. He had known I.E.T.D. men at Muscat, at Charbar, at Jask, at Henjam, at Bushire, at Bahrein and at Fao, and all up the line from Bushire to Teheran. They had always been helpful and cheerful. By the courtesy of Reuter's Agency and of the Department British Consular officials received Reuter's News free every day, and were not ungrateful to the Staff on whom fell the burden of receiving and transcribing the often lengthy summaries of English weather and English football

results. He had visited practically every land station shown on the map, and he could never be sufficiently grateful for the generous hospitality he had received from the superintendents and their wives. Nor could he refrain from mentioning the Persian linesmen on whose shoulders the welfare of the lines had rested since they were first started; and they were very near to his heart and half a dozen of them had been friends of his for the past twenty years. They were a very loyal lot of men, loyal alike to their own Government and to the Department who paid them. They had been attacked numberless times by brigands, and his recollection of the treatment of their claims was that they were not always treated so liberally by the Department as they should have been. He did not think there was any other parallel for a Department of a foreign Government, such as the Government of India or the Indian Office, controlling two or three thousand miles of land line in a foreign country with its own staff, and yet maintaining perfectly harmonious relations over a period of 50 years with the national government, in this case the Persian Government, and at the end of that 50 years getting a renewal of their concession for another 20 years—the best possible proof, if any proof was needed, of the ability with which the Department had been administered. When the Conventions were last renewed the Persian Government did not appear to have attempted to strike a hard bargain, but to have been well content to have the services of the Indo-European Department for a further period of 20 years. That reflected very high credit not only on the administration in England, but on the tact and discretion which must have characterised the action of the staff at all the various centres on the spot, each one of them a centre of intrigue at one time or another; the Telegraph Office at each place had contrived in times of difficulty to remain friendly with and indispensable to the party which was in power without antagonising the party which was outside the gates and ready to cut the telegraph lines.

The light-hearted nomad marksmen had always been a difficulty: insulators were an irresistible target: the white porcelain variety were found to offer such temptations to young marksmen that brown had been substituted in the hope that the duller colour would reduce their losses, but with moderate success and later on on certain stretches insulators were devised of cast-iron, with a porcelain insulator inside. Even that, however, had proved insufficient; the riflemen had got underneath and shot upwards! The posts too were invaluable rubbing posts for mangy camels, and made serviceable tent-poles and roof-bearers!

Residents in Persia and the Persian Gulf had every reason to be thoroughly satisfied with the speed and accuracy of the services at present existing. He could entirely confirm what Admiral Grant had said as to the immense value of the cables during the war to the Navy and to the British Army. During the war in Mesopotamia they were absolutely indispensable; and the Department had rendered great services. The staff in all offices was heavily drawn on for war purposes, which meant that those who were left had to do twice as much work as they did before, and as they had always had a full day's work it had been extremely hard on those who remained, without extra pay, or the stimulus of war service, and he would like to place on record his appreciation not only of those who joined up, but of those who had to remain behind.

He could not speak about telegraphic rates. That matter had been dealt with fairly fully by the lecturer, but he thought there was still room for improvement from the point of view of the public. Although the remark he was about to make was not strictly germane to the subject, as several representatives of telegraphic interests were present, he desired to express the hope that the next international

conference would be induced to dispense with the bugbear of the pronounceable word. He suggested that the international conferences were still dominated by the tradition of the longhand telegraphist, painfully taking down a group which he caught up by ear and recorded, whereas today practically all recording and despatching was done automatically. Any such relaxation of arbitrary rules would help to increase the purely commercial traffic and perhaps the friendly D.L.T'S would follow.

He wished Mr. Simpson would write a book. He himself had a shelf a long as his arm of books about the Indo-European Telegraph Department, by Sir Frederick Goldsmid, Sir J. Bateman Champain, Sir Robert Murdoch Smith, and others. There were stories in almost every book on Persia of the deeds of heroism of members of the staff, which well deserved to be put together into a single volume, and would make an epic. There was not a station from Bushire to Tcheran which had not half-a-dozen graves of men of the Department who were killed or had died in the execution of their duty—Major Wells, Sergeants Collings (killed at Khanch Zinian) Wittkugel (died of wounds with the S.P.R.) Hamilton, Hockey, Smith, and many others: in their death, as in their life, they upheld the good name of their native land; than such men Persia had no truer friends.

PANDIT AHLUVALIA GOPALJI said the audience had heard a very interesting and instructive story of a wonderful adventure, with a lot of chronological data, but the most noticeable point in the whole venture was that the thrills were British and the money was Indian. He thought that the Indians should have more of the thrills, and not only pay the money. The system was a very important nerve sustaining Imperialism, and unfortunately India had to pay for it.

SIR ARNOLD WILSON asked permission to reply to the previous speaker. The whole of the capital had been found by the Government of India, and when he had last been in the Persian Gulf and had pressed the Department to reduce rates, they replied that they were not in a position to do so because the Government of India insisted on getting a commercial return for the money invested; the Government of India was receiving between 7 and 8 per cent. That was not a bad return on the money, seeing that money could be borrowed in India at less than 5 per cent; the Pandit was perhaps unaware that three out of four of the telegraph staff were British Indian subjects.

Another point which Mr. Simpson had not brought out was that the reason why the Government of India in 1860 had undertaken the laying of the line was that the first cable laid under Government guarantee by a commercial company via the Red Sea and Aden to India had been a failure, and in the commercial and political interests of India it was decided to make every effort to connect India with Europe by land.

MR. ROBERT A-ABABRELTON, speaking as one of the oldest Fellows of the Royal Society of Arts, said he was deeply indebted to the Society for bringing up discussions on means of communication between the various parts of the British Empire. He hoped the Secretary would continue to bring up such subjects for discussion.

MR. C. SLOCOMBE said he had been attached to the Indo-European Telegraph Department in London for a great number of years, having served under several Directors-in-Chief. He was very pleased to hear the handsome tribute paid by the present Director-in-Chief to his staff in the remote regions of Persia and the Persian

Gulf. He had known a full generation of those men. Some of them were veterans in the service, and were approaching the age of retirement. Others had recently been sent out, but he knew that one and all of them were keen on their job, and their one object and aim in life was to be loyal to their Department and to their Chief, to keep the line in good working condition night and day, and to get the messages through as rapidly and as accurately as possible.

He had been very pleased to hear what the previous speaker had said with regard to the work of the Royal Society of Arts in stimulating lectures such as that which had just been delivered. It used to be said of a Government Department that to hear nothing whatever about it was a clear proof that it was well administered; and probably that was the reason why so little had been heard about the Indo-European Telegraph Department.

He had recently seen it remarked, in an excellent book by Mr. Brown, that those who were engaged in the work of international communication were assisting in the real material and spiritual progress of the world. That was so to-day, he had no doubt, but it had been much more true in the days when the pioneers, Colonel Goldsmid, Colonel Patrick Stewart, Sir John Champain and others, were doing their tremendous work in opening lines of communication between remote parts of the world. In those days the Crimea and the Mutiny were recent events, the Abyssinian campaign was in progress, and the people of England were very anxious for news, and it was therefore a matter of very great importance that those lines should be constructed. To show the feeling which had inspired those men, he wished to read a rough draft letter written by Major Champain, as he then was, to his Chief, at the end of which the following words occurred: "I cannot but think that in carrying out a grand enterprise like this we should be actuated by a higher motive than that of securing large returns only, and that by adding to our means of communication and reducing our charges we should place the use of the Indo-European Telegraph within the reach of all, and confer a vast benefit on the world."

That showed the spirit in which the work had been done in the old time. As to the future, it was on the knees of the gods; but whatever it might be, he was sure that under the inspiration of the past, and under the wise administration of the present Director-in-Chief, the staff would continue to give of their best, both at home and in the East, to the Government which they served and to the public which formed their customers.

On the motion of the Chairman, a vote of thanks to the lecturer was carried unanimously.

OBITUARY.

CHARLES SIMPSON BENTLEY.—The Society has lost one of its oldest members by the death of Mr. Charles S. Bentley, who was elected in 1872. He was born in 1844, and lived all his life in the northern outskirts of London. He was greatly interested in angling. He took part in the discussion on a paper on "The new Legislation on Fresh-water Fisheries," read before the Society by Mr. J. W. Willis-Bund in 1884, and in 1902 with two or three friends he founded the City of London Piscatorial Society, of which he was Honorary Secretary until 1924, when he was elected a Vice-President. For many years he was also a member of the Gresham Angling Society and published a treatise entitled "The Sense of Pain in Fishes."

Mr. Bentley was for many years a Fellow of the Royal Microscopical Society, and a member of the London Institution, where he acted as Honorary Auditor up to the time of his death. During the later part of his life he was a keen student of astronomy.

NOTES ON BOOKS.

BOMBAY INDUSTRIES : THE COTTON MILLS. Bombay : Published by the Indian Textile Journal.

In a review of the progress of the Textile Industry in Bombay under the title, "Bombay Industries : The Cotton Mills," Mr. Rutnagur has published a book which should command wide attention and interest.

The cotton mill industry is traced from its inception, and its progress up to the present day is fully outlined. In addition, everything having the remotest connection with the subject of the book is treated in an extremely full manner. The book is very well illustrated, has a wealth of statistics of a valuable character, and possesses summaries and indexes which make for great simplicity in reference.

A careful study of the book has failed to find a table which is not germane to the subject, or to find the omission of one which could have been included.

Mr. Rutnagur points out the difference between the management of Lancashire and of Bombay mills, the latter being managed by agents, many of whom have or had no technical training, and in this connection he shows that out of 175 mill directors controlling paid-up capital of almost 20 crores of rupees (£15,000,000) 95 are agency directors, that is, directors interested in the agency profits, a proportion which in this country would be considered undesirable.

The author fearlessly condemns the irregularities and mismanagement which often occurred and the methods often employed to obtain the passing of the Reports, and quotes in this connection a scathing article from the *Indian Textile Journal* of November, 1899.

The remuneration of the agents is discussed impartially as between a commission based on production of yarn which formerly was a usual method, and a percentage commission on profits which is now more in vogue, though the former system still exists in many mills.

The increase of weaving in mills is shown and the influences which have been at work towards this are explained, the principal one being the reduced dependence of the China market on India for yarn, owing to the enormous strides made by the Japan mill industry and its competition in China, and to the erection of mills in China itself.

There are most interesting chapters dealing among others with the Millowners' Association, the Chamber of Commerce, the East India Cotton Association and the Cotton Trade of Bombay, while the characteristics of Indian cotton are fully set out. One of the features of the book is the part dealing with labour in the mills, the life of the mill hand, his relations with his employers, and the efforts made by Government and by the employers for his amelioration, while the commencement of Labour Unions and Workers' Associations is sympathetically dealt with.

Although it is only twelve years since the first electric power was supplied to Bombay mills, there is now scarcely a single mill which does not utilise electric power for driving its machinery. with, consequently, a very beneficial effect on the atmosphere of Bombay, especially as the power is also supplied to other factories.

After a very careful study of the book we have only one criticism to offer. In the article on "The Purchase of Raw Cotton" the writer says: "Unfortunately, Bombay mills are handicapped to a large extent owing to the existence of five hedge contracts," and, later, "The element of speculation in buying futures could be reduced if there was a single hedge contract as in Liverpool and New York."

Liverpool has actually three hedge contracts, but, apart from this, a study of the history of the Liverpool and New York markets would show that in spite of only one hedge American contract, speculation and manipulation are as rife there as in any market we know. In any case, the American cotton crop lends itself to one hedge contract.

We are at one with the writer in admitting that if one hedge contract were possible for Indian cotton it would be desirable, but we are unable to visualise one hedge contract to include, say, Bengals and Sind—the shortest growths known—with Cambodia and Navsari cottons.

We fear that the endeavour to make tenderable in one contract the shortest growths known with the longest stapled East Indian cotton would make the contract a dangerous one to trade in, while it would be unfair to bar the short growths—Bengal and Sind—as they constitute a considerable proportion of the total Indian crop. Under the circumstances, we are of the opinion that the present five hedge contracts afford more reliable hedges.

It is impossible in a short review to touch on more than a few of the excellent features of the book, but to anyone interested in the Bombay mill industry it will appeal for its completeness, while to any one who was or is still connected with this important branch of Bombay trade the book will have an additional interest on account of the personal references of which it contains so many.

COMETS AND THE SUN: NEW THEORIES REGARDING THEIR STRUCTURE. By John W. Weir, M.D. With illustrations. London: Longmans, Green and Co. 12/6.

This remarkable and delightfully speculative volume with its XI plates and far-reaching studies of early and late work, comes from one who thinks it possible or probable that the sun is a first creation from which we derive not only the energy but also the material of our earth.

Much prominence is given to recent work done at the Cape Observatory: the frontispiece and many of the illustrations having originated in South Africa. Plate VIII, The Great Scarlet Solar Prominences, which is opposite p. 36, may serve as giving an idea not only of the energetic predominance of the sun, but also of its magnitude as compared with the earth. The flames from the prominences are described as rising sometimes to a height of 500,000 miles or 60 times the diameter of the earth.

Broadly speaking, the author's theory of cosmic origins is one which may be regarded as an opposite of the nebular condensation view, but a reference to p. 51 shows that a nebular hypothesis may lurk far in the background. We, nevertheless, gather that the active or brilliant sun or star is the proximate unit of origin in Dr. Weir's system, planets and comets being occasional throw-offs.

Comets are studied in considerable detail. On p. 7 we are reminded that the transparent portions of a comet both reflect and refract light, and on pp. 8, 9, 10, also in other places, a definite transparent envelope is considered; this having perhaps some parity with the region of frozen nitrogen which recently has been supposed to exist in the remote parts of the terrestrial atmosphere.

Although we can find nothing definitely contrary to the accepted statics and dynamics, we can quite understand caution and argument before acceptance.

THE WHITWORTH BOOK. Prepared by the Whitworth Society. Honorary Editor David Allan Low. With Portrait. London: Longmans, Green and Co., Limited. 10s. 6d. net.

The portrait used as a frontispiece in this volume gives an admirable first impression of Joseph Whitworth, whose leading sentiments in work were extreme accuracy and unbending stability; both of these being embodied in his millionth of an inch measuring machine. To get a good view of Whitworth as the culminating link in a chain of notable British mechanics, we turn to Dr. Andrew Wynter's second series of essays on "Our Social Bees," Hardwicke, 1869. On p. 172 of this book Bramah is pictured in his workshop as talking to a youth who had been employed in the Arsenal at Woolwich. The youth "pointing to an old and worn-out vice asked if the fact of his being able to renew it in the course of the afternoon would be accepted as his diploma of proficiency." The vice having been renewed, the youth, Henry Maudslay, entered into service with Bramah, and the slide-rest soon came into practical being. Afterwards the planing machine took shape, and Whitworth, who co-operated with Maudslay, devised the "Jim-Crow" action for reversing the cutter. Here was the first effective "machine-tool" in the modern sense of the term, as derived from the slide-rest.

In the volume before us is to be found a detailed account of the remarkable social work effected by Joseph Whitworth in his later life, when financially prosperous. His scheme of scholarships originated in 1868, and up to the end of 1925 the Whitworth Society has traced 1,401 men who have benefited by the scheme.

The general plan of the book is good, and everyone wishing to obtain full particulars as to the Whitworth Trust, and regulations as to Scholarships, also a short biographical notice of every Whitworth scholar who can be traced, should obtain this volume of over 300 pages.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, MARCH 5. Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Mr. G. H. Jack, "Ancient Bridges."
Automobile Engineers, Institution of, at the Merchant Venturers' Technical College, Bristol, 6.45 p.m. Mr. G. L. Ensor, "Notes on the Single Sleeve-Valve Principle."
Chemical Industry, Society of, at Burlington House, W. 8 p.m. Prof. G. T. Morgan and Messrs. R. Taylor and T. J. Hedley, "Syntheses under High Pressure."
Electrical Engineers, Institution of, Savoy Place, W.C. 7 p.m.
Farmers' Club, at the Hotel Metropole, Northumberland Avenue, S.W. 4 p.m. Mr. C. Dampier-Whetham, "The Effect of Monetary Instability upon Agriculture."
Geographical Society, at the Æolian Hall, 135, New Bond Street, W. 8.30 p.m. Mr. D. R. G. Cameron, "Across the Sahara from Kano to Warghla."
Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Dr. Erwin Schrödinger, "Wave Mechanics." (Lecture I.)
Surveyors' Institution, at 12, Great George Street, S.W. 8 p.m.
Transport, Institute of, 15, Savoy Street, W.C. 5.30 p.m. Air Vice-Marshal Sir W. Sefton Branner, "Progress in Air Transport."
University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Prince D. S. Mirsky, "The Russian Novel after 1880." (Lecture VII.)
At King's College, Strand, W.C. 5.30 p.m. The Rev. C. F. Rogers, "Ecclesiastical Music." (Lecture IV.)

At University College, Gower Street, W.C. 2 p.m. Signor Camillo Pellizzi, "The Italian Epic."
5 p.m. Dr. A. S. Parkes, "The Internal Secretions of the Gonads." (Lecture VI.)
Victoria Institute, at the Central Hall, Westminster S.W. 4.30 p.m. The Rev. Canon H. K. Cunningham, "The Doctrine of Forgiveness through the Cross of Christ."
TUESDAY, MARCH 6. Automobile Engineers, Institution of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 7.15 p.m. Dr. F. W. Lancaster, "Automobile Steering Gear—Problems and Mechanism."
Civil Engineers, Institution of, Great George Street, S.W. 6 p.m.
Colonial Institute, at the Hotel Victoria, Northumberland Avenue, W.C. 8.30 p.m.
Industrial Transport Association, at Anderson's Hotel, Fleet Street, E.C. 6.30 p.m. Discussion on "Shipping Freight Anomalies."
Metals, Institute of, at Armstrong College, Newcastle-on-Tyne, 7.30 p.m. Annual General Meeting.
North East Coast Institution of Engineers and Shipbuilders, at the Cleveland Scientific Technical Institution, Middlesbrough, 7.30 p.m. Mr. C. H. Cooke, "Lubrication."
Photographic Society, 35, Russell Square, W.C. 7 p.m. Meeting arranged by the Pictorial Group.
Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Prof. J. S. Huxley, "The Behaviour of Animals." (Lecture III.)
Transport, Institute of, at the University, Bristol, 5.30 p.m. Prof. W. H. Whyte, "The Influence of Transport on Industrial Development."
University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Sir Bernard Pares, "Russian History from Peter the Great to 1861." (Lecture VII.)
At King's College, Strand, W.C. 5 p.m. Dr. J. A.

- Hewitt, "Integration in the Nervous System." (Lecture VIII.)
At the Natural History Museum, South Kensington, S.W. 5.15 p.m. Mr. J. Ramsbottom, "The Evolution and Classification of Fungi." (Lecture I.)
At University College, Gower Street, W.C. 5.30 p.m. Prof. Dr. J. G. Robertson, "Henrik Ibsen." (Lecture II.)
8.15 p.m. Miss E. Jeffries Davis, "More London Place-Names." (Lecture V.)
- WEDNESDAY, MARCH 7.** Analysts, Society of Public, Burlington House, W. 8 p.m. (1) Professor T. P. Hilditch, "Composition of the Fatty Acids present as Glycerides in Elasmobranch Oils." (2) Mr. R. T. Thomson, "Behaviour of Indicators in the Titration of Ammonia, Sodium and Calcium Phosphates, the Methylamines, Pyridine Bases and Boric Acid." (3) Mr. H. R. Jensen, "Cacao Tannin."
Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Mr. J. H. Jarman, "General Building Materials."
Civil Engineers, Institution of, Great George Street, S.W. 6 p.m. Mr. J. M. Kennedy, "The Effect of Load-Factor on Works Cost in Electricity Generating Stations."
Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m.
Geological Society, Burlington House, W. 5.30 p.m. Miss H. K. Cargill, Mr. L. Hawkes and Miss J. A. Ledeboer, "The Major Intrusions of South-Eastern Ireland."
Heating and Ventilating Engineers, Institution of, at Caxton Hall, Westminster, S.W. 7 p.m. Mr. H. R. Hiscott, "The Manufacture of Malleable Iron Pipe Fittings."
Metals, Institute of, at the Institution of Mechanical Engineers, Storey's Gate, S.W. 10 a.m. to 12.30 p.m. Dr. W. Rosenhain, Presidential Address. (1) Messrs. S. Beckinsale and H. Waterhouse, "The Deterioration of Lead Cable Sheathing by Cracking, and its Prevention." (2) Dr. Max Haas, "The Dilatometric Study of Light Metals." (3) Dr. Ezer Griffiths and Mr. F. H. Schofield, "The Thermal and Electrical Conductivity of some Aluminium Alloys and Bronzes." (4) Mr. R. Chadwick, "The Constitution of the Alloys of Magnesium and Zinc." 2 p.m. to 4 p.m. (1) Mr. Hugh O'Neill, "Historical Note on Density Changes caused by Cold-working Metals." (2) Major F. S. Grimston, "Season-Cracking of Small Arms Cartridge Cases during Manufacture." (3) Mr. F. Hargreaves, "The Ball Hardness and the Cold-Working of Soft Metals and Eutectics." (4) Mr. W. L. Kent, "The Behaviour of Metals and Alloys during Hot-Forging." (5) Mr. William A. Cowan, "Minute Shrinkage Cavities in Some Cast Alloys of Heterogeneous Structure." (6) Mr. William A. Cowan, "Notes on the Composition of Old Roman Lead."
Microscopical Society, 20, Hanover Square, W. Meeting of the Biological Section.
Public Health, Royal Institute of, 37, Russell Square, W.C. 4.30 p.m. Dr. G. Roche Lynch, "Some Problems in Medico-Legal Practice."
Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Dr. Erwin Schrödinger, "Wave Mechanics." (Lecture II.)
Sanitary Engineers, Institution of, at Denison House, 296, Vauxhall Bridge Road, S.W. 6.30 p.m. Mr. W. Lionel Jenkins, "Tidal Rivers and Floods."
University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. Otakar Vocado, "The Modern Czech Theatre." (Lecture I.)
At King's College, Strand, W.C. 5.30 p.m. Prof. R. A. Sampson, "In What Degree is Science True?"
At University College, Gower Street, W.C. 5.30 p.m. Mr. Albert Mansbridge, "The Citizen and the Librarian." 6 p.m. Prof. Dr. A. L. Bowley, "Measurement by Index Numbers—Theory and Application to Recent Economic History." (Lecture VI.)
- THURSDAY, MARCH 8.** Chadwick Public Lecture, at Stuart Hall, Norwich, 8 p.m. Dr. F. W. Alexander, "The Value of Sunlight."
Chemical Engineers, Institution of, at the New Princes' Restaurant, Jermyn Street, S.W. 5 p.m. Prof. B. W. Holman, "The Theory of Magnetic Separation." 8 p.m. Dr. Burrows Moore, "The Combustion of Powdered Coal."
Goldsmiths' Hall, Foster Lane, E.C. 7 p.m. Mr. Omar Ramsden, "Some Aspects of Modern Silver Production."
Historical Society, 22, Russell Square, W.C. 5 p.m. Mr. A. E. Stamp, "The Historical Student and the Public Record Office."
Industrial Psychology, Institute of, at the Royal Society of Arts, Adelphi, W.C. 5.15 p.m.
L.C.C. The Geoffrey Museum, Kingsland Road, E. 7.30 p.m. Mr. James Rudd, "The Advantages of Modern Furniture."
Metals, Institute of, at the Institution of Mechanical Engineers, Storey's Gate, S.W. 10 a.m. to 1 p.m. (1) Mr. G. I. Bailey, "The Influence of Dissolved Gases on the Soundness of 70:30 Brass Ingots." (2) Dr. A. L. Norbury, "The Effect of Quenching and Tempering on the Mechanical Properties of Standard Silver." (3) Dr. J. Newton Friend, and Mr. W. E. Thomeycroft, "An Example of Roman Copper Soldering and Welding from Uriconium." (4) Dr. J. Newton Friend, "The Relative Corrosibilities of Ferrous and Non-Ferrous Metals and Alloys, Part I.—The Results of Four Years' Exposure in the Bristol Channel." (5) Dr. T. E. Allibone and Mr. C. Sykes, "The Alloys of Zirconium.—I." (6) Dr. Tsutomu Matsuda, "On the Quenching and Tempering of Brass, Bronze and Aluminium-Bronze."
Oil and Colour Chemists' Association, at 8, St. Martin's Place, W.C. 7.30 p.m. Dr. E. W. J. Mardles, "Notes on Aeronautical Paints and Varnishes."
Photographic Society, 35, Russell Square, W.C. 7 p.m. Annual General Meeting of the Colour Group.
Royal Society, Burlington House, W. 4.30 p.m.
Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Dr. J. J. Fox, "Optics and Chemistry."
University of London, at University College, Gower Street, W.C. 5.30 p.m. Major-Gen. Sir John Burnett-Stuart, "The Development of Mechanisation." 5.40 p.m. Prof. E. W. Tristram, "English Medieval Painting." (Lecture II.)
Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Mr. H. Clifford-Smith, "Furniture as shown in Pictures."
- FRIDAY, MARCH 9.** Chemical Engineers, Institution of, at the New Princes' Restaurant, Jermyn Street, S.W. 11.30 a.m. Sir Alexander Gibb, Presidential Address, "The Economics of Power as applied to Chemical Engineering." 2.15 p.m. Dr. O. Spengler, "The Treatment of Effluents from Beet Sugar Factories."
Engineering Inspection, Institution of, at the Royal Society of Arts, Adelphi, W.C. 7.30 p.m. Mr. L. Nicholson.
Malacological Society, at Burlington House, W. 6 p.m.
Metals, Institute of, at the Applied Science Department, University of Sheffield. 7.30 p.m. Mr. W. R. Barclay, "Special Alloys in relation to the Corrosion Problem."
North-East Coast Institution of Engineers and Shipbuilders, at the Mining Institute, Newcastle-on-Tyne. 6 p.m. Mr. J. S. Brown, "Measurement of Power."
Oil and Colour Chemists' Association, at Milton Hall, Deansgate, Manchester. 7.30 p.m. Dr. J. N. Friend, "Researches on the Preservation of Iron and Steel with Paint."
Physical Society, at the Imperial College of Science and Technology, South Kensington, S.W. 5 p.m. Sir Joseph Thomson, O.M., F.R.S., "Electrodeless Discharge through Gases." (Guthrie Lecture.)
Royal Institution, 21, Albemarle Street, W. 9 p.m. "The Sun's Outer Atmosphere."
Transport, Institute of, at the Town Hall, Newcastle-on-Tyne. 5 p.m. Mr. R. R. Pecorini, "Some Applications of Radio to the Science of Transport."
University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Julian Krzyzanowski, "Polish Literature." (Lecture VII.)
At University College, Gower Street, W.C. 5 p.m. Mr. C. F. A. Pantin, "Comparative Physiology." (Lecture IX.)
- SATURDAY, MARCH 10.** L.C.C. The Horniman Museum, Forest Hill, S.E., at 3.30 p.m. Mr. C. Daryl Forde, "The First Metal-Workers."
Royal Institution, 21, Albemarle Street, W. 3 p.m. Sir Ernest Rutherford, "The Transformation of Matter."

JOURNAL OF THE ROYAL SOCIETY OF ARTS

No. 3929.

VOL. LXXVI.

FRIDAY, MARCH 9th, 1928.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK.

WEDNESDAY, MARCH 14th, at 8 p.m. (Ordinary Meeting.) HAROLD G. BROWN, A.M.I.E.E., of the D.P. Battery Co., Ltd., "The Lead Acid Cell: its place in Modern Industry." WILLIAM McCLELLAND, Esq., C.B., O.B.E., M.I.E.E., Director, Electrical Engineering Department, Admiralty, will preside.

DOMINIONS AND COLONIES SECTION.

TUESDAY, FEBRUARY 28th, 1928. EDWARD BRUCE ALEXANDER, Esq., C.M.G., in the Chair.

A paper entitled, "The Ancient Civilisation of Ceylon" was read by SIR STEPHEN MONTAGU BURROWS, C.I.E. (late Ceylon Civil Service). The paper and discussion will be published in the *Journal* dated April 27th.

FOURTEENTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 29th, 1928. THE RIGHT HON. GEORGE N. BARNES, P.C., C.H., in the Chair.

A paper entitled "Industry Fifty Years Hence" was read by ARCHIBALD CRAWFORD, Esq., K.C., Director of the Economic League.

The paper and discussion will be published in the *Journal* dated May 4th.

REPRINT OF CANTOR LECTURES.

The four Cantor Lectures on "Alloy Steels: their Manufacture, Properties and Uses," by Professor H. C. H. Carpenter, M.A., A.R.S.M., F.R.S., recently published in the *Journal* have been reprinted in pamphlet form (price 2s. 6d.) and can be obtained from the Secretary, Royal Society of Arts, John Street, Adelphi, W.C.2.

A complete list of Cantor, Howard and other lectures, which are available in pamphlet form, can also be had on application.

PRESERVATION OF ANCIENT COTTAGES.

ARLINGTON ROW, BIBURY.

The following letter has been issued appealing for a sum of £2,000 to repair and preserve the beautiful group of cottages known as Arlington Row, Bibury:—

ROYAL SOCIETY OF ARTS,
JOHN STREET, ADELPHI,
LONDON, W.C.2.

SIR,—“ Surely,” wrote William Morris, “ Bibury is the loveliest village in England.” The owner of Arlington Row, perhaps the most beautiful group of cottages in Bibury, finds that he is no longer able to keep them in proper repair. He is, however, anxious that they should not be spoiled, and with the object of securing their permanent preservation has offered to hand them over for a small figure to the Royal Society of Arts, whose Scheme for the Preservation of Ancient Cottages was inaugurated a year ago by the Prime Minister, on condition that the necessary work of repair is carried out.

The beautiful stone-slatted roofs are in imminent danger of collapse, and the Society's architect, who is familiar with work of this kind, estimates that at least £1,000 will be required to put the eight cottages into a satisfactory condition. The rents of the cottages, which the Society would certainly not propose to raise (nor would it propose to change the nature of their occupation), are insufficient to pay for the cost of maintenance, and the Society therefore hopes, with the help of those interested in such work, to inaugurate a special repair fund of £500, the interest of which may be ear-marked for this purpose. The total amount aimed at, therefore, is £2,000, which will provide for the purchase of the eight cottages, the repairs immediately necessary, and also for a permanent repair fund. If this sum can be raised, the cottages, after the necessary work has been carried out, will be handed over by the Royal Society of Arts to a Local Committee of Management.

The object in view is, we feel sure, one which lies near the heart of all lovers of the matchless Cotswold country, and we appeal to them with confidence to help us to preserve the peculiar charm and character of Bibury and to hand it on intact as a continuing joy for those who come after us.

We are, Sir,

Yours faithfully,

BEAUCHAMP,

Lord Lieutenant of the County of Gloucester.

A. C. GLOUCESTER

BATHURST

G. A. H. WILLS

WALTER TAPPER,

President, Royal Institute of British Architects.

PHILIP MAGNUS,

Chairman, Council of the Royal Society of Arts.

FRANK BAINES,

Chairman, Royal Society of Arts Fund for the
Preservation of Ancient Cottages.

Subscriptions to the Fund will be gratefully acknowledged by the Secretary,
Royal Society of Arts, John Street, Adelphi, W.C.2.



Photograph by W. Dennis Moss, Cirencester.

Arlington Row, Bibury, Glos.

The following donations have been promised :—

	£	s.	d.
Royal Society of Arts Fund for the Preservation of Ancient Cottages	100	0	0
Sir Gilbert Wills, Bt., O.B.E.	50	0	0
Miss M. Budgett	2	2	0

THE ALBERT MEDAL.

The Council will proceed to consider the award of the Albert Medal of the Royal Society of Arts for 1928 early in May next, and they therefore invite Fellows of the Society to forward to the Secretary on or before Saturday, March 24th, the names of such men of high distinction as they may think worthy of this honour. The medal was struck to reward "distinguished merit in promoting Arts, Manufactures, and Commerce," and has been awarded as follows in previous years :—

1864, Sir Rowland Hill, K.C.B., F.R.S.

1865, His Imperial Majesty Napoleon III.

1866, Michael Faraday, D.C.L., F.R.S.

1867, Sir W. Fothergill Cooke and Sir Charles Wheatstone, F.R.S.

1868, Sir Joseph Whitworth, LL.D., F.R.S.

1869, Baron Justus von Liebig.

1870, Vicomte Ferdinand de Lesseps, Hon. G.C.S.I.

1871, Sir Henry Cole, K.C.B.

1872, Sir Henry Bessemer, F.R.S.

1873, Michel Eugene Chevreul, For. Memb. R.S.

1874, Sir C. W. Siemens, D.C.L., F.R.S.

1875, Michel Chevalier.

1876, Sir George B. Airy, K.C.B., F.R.S.

1877, Jean Baptiste Dumas, For. Memb. R.S.

1878, Sir Wm. G. Armstrong (afterwards Lord Armstrong), C.B., D.C.L., F.R.S.

1879, Sir William Thomson (afterwards Lord Kelvin), O.M., LL.D., D.C.L., F.R.S.

1880, James Prescott Joule, LL.D., D.C.L., F.R.S.

1881, Professor August Wilhelm Hofmann, M.D., LL.D., F.R.S.

1882, Louis Pasteur.

1883, Sir Joseph Dalton Hooker, K.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S.

1884, Captain James Buchanan Eads.

1885, Sir Henry Doulton.

1886, Samuel Cunliffe Lister (afterwards Lord Masham).

1887, HER MAJESTY QUEEN VICTORIA.

1888, Professor Hermann Louis Helmholtz.

1889, John Percy, LL.D., F.R.S.

1890, Sir William Henry Perkin, F.R.S.

1891, Sir Frederick Abel, Bt., G.C.V.O., K.C.B., D.C.L., D.Sc., F.R.S.

1892, Thomas Alva Edison.

1893, Sir John Bennet Lawes, Bt., F.R.S., and Sir Henry Gilbert, Ph.D., F.R.S.

1894, Sir Joseph (afterwards Lord) Lister, F.R.S.

1895, Sir Isaac Lowthian Bell, Bt., F.R.S.

1896, Professor David Edward Hughes, F.R.S.

1897, George James Symons, F.R.S.

1898, Professor Robert Wilhelm Bunsen, M.D., For. Memb. R.S.

- 1899, Sir William Crookes, O.M., F.R.S.
 1900, Henry Wilde, F.R.S.
 1901, HIS MAJESTY KING EDWARD VII.
 1902, Professor Alexander Graham Bell.
 1903, Sir Charles Augustus Hartley, K.C.M.G.
 1904, Walter Crane.
 1905, Lord Rayleigh, O.M., D.C.L., Sc.D., F.R.S.
 1906, Sir Joseph Wilson Swan, M.A., D.Sc., F.R.S.
 1907, The Earl of Cromer, O.M., G.C.B., G.C.M.G., K.C.S.I., C.I.E.
 1908, Sir James Dewar, M.A., D.Sc., LL.D., F.R.S.
 1909, Sir Andrew Nobel, K.C.B., D.Sc., D.C.L., F.R.S.
 1910, Madame Curie.
 1911, The Hon. Sir Charles Algernon Parsons, K.C.B., LL.D., F.R.S.
 1912, The Right Hon. Lord Strathcona and Mount Royal, G.C.M.G., G.C.V.O., LL.D., D.C.L., F.R.S.
 1913, HIS MAJESTY KING GEORGE V.
 1914, Chevalier Guglielmo Marconi, G.C.V.O., LL.D., D.Sc.
 1915, Sir Joseph John Thomson, O.M. D.Sc., LL.D., F.R.S.
 1916, Professor Elias Metchnikoff.
 1917, Orville Wright.
 1918, Sir Richard Tetley Glazebrook, C.B., Sc.D., F.R.S.
 1919, Sir Oliver Joseph Lodge, D.Sc., LL.D., F.R.S.
 1920, Professor Albert Abraham Michelson, For. Memb. R.S.
 1921, Professor John Ambrose Fleming, D.Sc., F.R.S.
 1922, Sir Dugald Clerk, K.B.E., D.Sc., LL.D., F.R.S.
 1923, Major-General Sir David Bruce, K.C.B., D.Sc., LL.D., F.R.C.P., F.R.S., and Colonel Sir Ronald Ross, K.C.B., K.C.M.G., D.Sc., LL.D., M.D., F.R.C.S., F.R.S.
 1924, H.R.H. THE PRINCE OF WALES, K.G.
 1925, Lieut.-Colonel Sir David Prain, C.M.G., C.I.E., M.B., LL.D., F.R.S.
 1926, Professor Paul Sabatier, Member of the Institute of France, For. Memb. R.S., Davy Medallist, and Nobel Prizeman.
 1927, Sir Aston Webb, G.C.V.O., C.B., P.R.A., 1919-24, P.R.I.B.A., 1902-4, F.S.A., LL.D.

PROCEEDINGS OF THE SOCIETY.

NINTH ORDINARY MEETING.

WEDNESDAY, JANUARY 25TH, 1928.

DONALD WIPPELL, Esq., in the Chair.

THE CHAIRMAN said he felt it an honour to address a meeting of the Royal Society of Arts, and a privilege and pleasure to introduce Mr. H. De Koningh to the meeting. Some of those present might have availed themselves in the past of his technical skill in his craft, and all who were interested in the subject must have read his able translation of "Enamelling on Metal." Those who had not read his new book, "The Preparation of Precious and Other Metal Work for Enamelling" should do so. The title of that book did not do it justice, for in addition to giving a description of how to prepare art metal for enamelling it contained three very interesting chapters, one giving a comparison of the modern

enamelling shop with its mediaeval prototype and oriental contemporary, another dealing with the various classes of enamels, and the third containing a brief historical survey.

The following paper was then read:—

ENAMELS, SECULAR AND ECCLESIASTIC.

By H. DE KONINGH.

The art of enamelling is that of decorating articles made of certain metals with a vitreous substance resembling the flint glass of commerce, but somewhat more fusible and coloured by means of various metallic salts, mainly the oxides, such as those of cobalt, copper, iron, manganese, etc. Enamels for all artistic and high-class metal work are prepared in comparatively small quantities, from two to four or five kilos at a melting. Certain fluxes, as we call the clear colourless enamels, are prepared in larger quantities, in the same manner as is flint glass, as are also the enamels for commercial use on a large scale, such as advertising signs, baths, domestic hardware, etc., but with these latter we have no present concern. Enamels are supplied for use in the form of cakes, lumps and occasionally rods. These are broken with an ordinary hammer to a suitable size, and a sufficient quantity for immediate use is ground in plain water, in an agate mortar; the degree of fineness required will be determined partly by the nature of the particular enamel and partly by the nature of the article to be enamelled, but the average "grit" will be that of a fine sand. After grinding, the enamel is copiously washed with clean water to remove every trace of mud or silt which forms in the grinding, and is then placed in china or glass pots provided with covers. It is now ready for use.

The process of applying the enamel is this: The workman having his pots containing the various colours he requires ranged on the bench in front of him, and the article to be enamelled properly cleaned and dried, takes up on the end of a thin steel spatula a blob of the wet enamel, which he applies to the proper place on the article, a dexterous little wiggle of the spatula spreads this blob fairly evenly; he then takes up another blob and applies it alongside the first, and so on, until the whole of the appointed place is covered. He then dries out the excess moisture by means of a piece of clean dry linen folded into a pad in the same manner as one folds a pocket handkerchief; this is gently pressed against the side of the enamel, and quickly absorbs the greater part of the moisture; the article is then placed near the furnace that every trace of moisture may be expelled and when this is completed, in from five to twenty minutes, the article is very carefully placed on a fireclay slab, or planche, and introduced into the furnace, which should be at its full working heat: in a short while, varying from a few seconds to several minutes, according to the size and nature of the article, it will be noticed that the fine

particles of enamel begin to fuse and run together. This is a critical moment, for while the process of fusion must be carried far enough, it must not proceed too far or the enamel will suffer, and in extreme cases the metal itself might actually melt; as soon as the fusion—or firing as we call it—is judged to be complete, the article is quickly withdrawn from the furnace and put on one side to cool. It will then be seen that the particles of enamel have coalesced and present a shiny, homogeneous, slightly undulating surface, and all being well, this thin coating of enamel will adhere firmly to the metal; a further coat or coats, as may be necessary, are then applied and fired in the same manner as the first. In some cases the degree of "finish" thus attained will be sufficient; in others, the surface of the enamel is ground over with such abrasives as emery or carborundum and thoroughly cleansed with clear water. Any little hollows which may remain in the enamel are then filled in, and the article is again fired. A further touch over with a file may be necessary to remove any little lumpiness: then another thorough cleansing and a final firing to restore the glaze, and the work is complete.

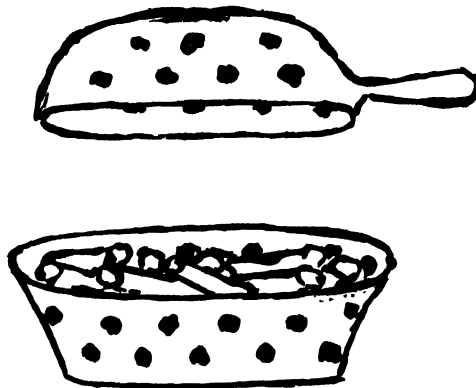


FIG 1.—Diagram of the earliest known type of Enamelling Furnace, with cover.

That, briefly, is the method of enamelling—very simple in theory, but a very different matter in practice, when many factors come into play, such as the nature of the metal employed in making the article to be enamelled, *e.g.*, gold, silver or copper, the quantity and composition of their alloys, the suitability or otherwise of any particular enamel for certain classes of work, and a multitude of details into which it is impossible to enter here, but which I have described fully and practically elsewhere.* I have, of course, only explained here the procedure with a simple article requiring at most three or four fires, but many articles, or varying styles of enamels, will require anything up to ten or a dozen firings, but, throughout, the principles remain exactly the

*"The Preparation of Precious and other Metals for Enamelling." H. de Koningh. "Enamelling on Metal." L. E. Millenet, translated by H. de Koningh. Crosby Lockwood and Son.

same ; in fact, it is interesting to remember also that in whatever age the art has been practised and in whatever land, the essential processes just described have remained virtually unchanged. Improvements there have been, of course, but these have been purely on the mechanical side, better and more varied tools, a greater range of colours, the use of lathes of various types and, especially, improved types of furnaces.

In Fig. 1 we have a rough design, so far as we can understand the description handed down to us, of the earliest known type of enamelling furnace, if we can call it a furnace : the lower part, indeed, is very much like the iron braziers used by the night-watchmen who guard our street excavations, and was filled with burning charcoal. When this was well alight, the article to be fired, resting on a sheet of iron, was placed on the hot charcoal ; then the upper part, which was provided with a handle, was placed over this and covered also with charcoal, and the apprentice hopped round with a pair of bellows or a fan to keep the whole thing glowing. The master observed the progress of events through one of the holes in the upper part, which was kept clear for the purpose : when he judged that the firing was complete the burning charcoal was removed from the top and the whole contraption put on one side to cool, a chancy business at the best, and when I think of the wonderful results obtained by such inadequate means, I metaphorically raise my hat to those long-gone fellow craftsmen of mine.

The next development in this direction is shown in an interesting print* drawn by himself of the workshop of Etienne Delaune, a goldsmith of Paris, 1576, which, allowing for the difference in costume, could well represent a goldsmith's workshop of to-day, or if the wire-drawing bench on the left were replaced by a polishing bench, it would do equally well for that of an enameller, as there is a furnace on the right (the goldsmiths of those days were their own enamellers) : this furnace is built into the chimney breast, the front, which is removable, being formed of a stout iron plate with suitable apertures ; the fuel was charcoal, replaced at a later period by coke ; the furnace was provided with a fireclay muffle arch to keep the fuel and dust off the work being fired. This type of furnace remained in use for a long period : in fact, in my young days, before gas was thought of, except for very small furnaces, I worked at such a furnace, and as the iron front used to get red hot, firing a large article was no pleasant task.

Another interesting picture* from Jacob's " Jeypore Enamels " shows a group of Jeypore enamellers at work, the period being about 1880. It will be noticed that, allowing for the difference in environment, there is quite a marked family resemblance between the workshop of the Frenchman, Etienne Delaune, and of the Sikh, Gumah Singh, although the furnace of the latter is very primitive and appears to be a development of the first type illustrated in Fig. 1.

*Reproduced in " The Preparation of Precious and other Metals for Enamelling."

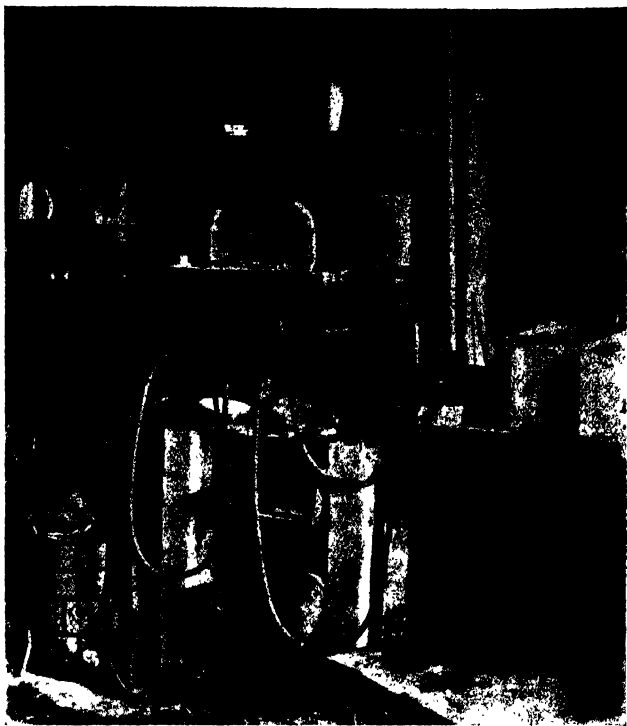


FIG 2.—A corner of the Lecturer's Workshop, showing two gas-heated Muffle Furnaces and, on floor, a gas-heated Melting Furnace.

In Fig. 2 we have the most modern type of gas-heated muffle furnace: the two injector burners use gas at the ordinary house pressure, but the air is pumped in at high pressure by means of a compressor. A furnace of this type will attain a heat of about 1100° Centigrade. The small furnace on the left is normally used without any forced draught; and it will be noticed that on the iron plate a few inches below the bottom of the furnace are two articles of which the enamel is drying in the manner already described. At the left, on the floor, is a kiln-shaped gas furnace (the top has been removed) used for melting; there is a skittle-shaped pot on the top of the larger furnace used for this purpose: this will take a charge of about $3\frac{1}{2}$ lbs. of enamel.

That the art of enamelling is of great antiquity there is no doubt, but as to when and where, or by whom, it was first practised we know nothing definite. I have my own theory, of course, which naturally differs from that of the other learned gentlemen who have written on the subject, but of these learned archæologists, few, if any, have had any practical experience and there has been considerable confusion between three types of decoration employed by the ancients, namely, true vitreous enamels, inlays of thin pieces of coloured

glass and some kind of composition. There are, however, a few examples of undoubtedly vitreous enamels dating back to the pre-Christian era, and I propose to show you some of these, together with examples from succeeding periods down to the present day, and leave it to you to form theories of your own if you are so inclined.

The earliest known type of enamels (and in this connection I now refer to the completed article) are in the cloisonné style; that is to say, the 'cloisons' or cells which contain the enamel were formed from thin flat wires bent to the required shapes and lightly soldered on to the surface of the articles to be enamelled. The spaces thus formed were then filled in with enamel in the manner I have already described, the surface being finally ground over and polished so that the upper edges of the wires and the surface of the enamel were perfectly level.

There were certain difficulties in the way of obtaining photographs of these articles so I have had to resort to making sketches of them, but they serve to illustrate the old axiom, "There is nothing new under the sun," for the rings Nos. 1 and 2 (Fig. 3), though quite modern in appearance, are of the

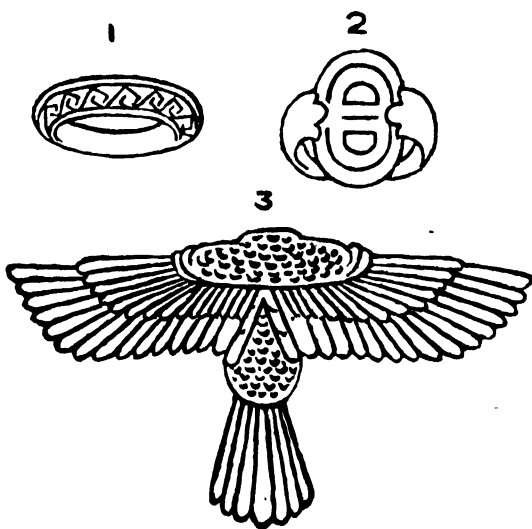


FIG 3.—Nos. 1 and 2, Rings of the Greek Mycenaean period (about 1100 B.C.). Cloisonné Enamel. No. 3, Egyptian Cloisonné Enamel. Period uncertain. All on Gold.

Greek Mycenaean period and are considered to date from about 1100 B.C. They are cloisonné, the gold edges and lines having been applied as I have just described. I was privileged by the authorities of the British Museum to examine one of these rings very closely a good many years ago, and in my opinion it is undoubtedly vitreous enamel, but very much decomposed owing to the action of the damp earth in which it had been buried for many

centuries, and it is the earliest example of enamelling of which I have personal knowledge. There is in the Boulak Museum, Cairo, an ornament from the tomb of Queen Aerhotep, about 1700 B.C., said to be decorated with a kind of enamel, and if this statement is correct, it would set the date still earlier. The next authentic pieces to which a reasonably approximate date can be set are several gold enamelled ornaments found in the tumuli at Kertch in the Crimea about 1840. These are of Graeco-Scythian workmanship and date from the fourth to the third centuries B.C. I do not think any examples of these articles ever found their way to this country. No. 3, a flying hawk of typically Egyptian design, is in the British Museum, but, unfortunately, nothing is known of its origin. It is cloisonné enamel, and from the general style I am inclined to think it is of Greek workmanship, but probably of later date than the two rings. Of course, the dates I have mentioned are merely approximate, but from this period we begin to walk on much firmer ground. The scene, however, shifts from the East to the West of Europe, and in the first century B.C. we find the earliest of the well-known Keltic enamels. Whether the art was imported from the East, or whether, as is more probable, it sprang up spontaneously in the West, we have no means of deciding, but there is a significant difference of style. In Fig. 4 we get a variation in the method; here the spaces to be enamelled are sunk with the graving tool or chisel—that is the *champlévé* style—or the article is modelled and cast, the enamel parts being recessed; broader bands and masses of metal separate the colours. The work of the Keltic (late Iron Age), and of the Anglo-Roman period which succeeded it, is marked by a correctness of design and a freedom

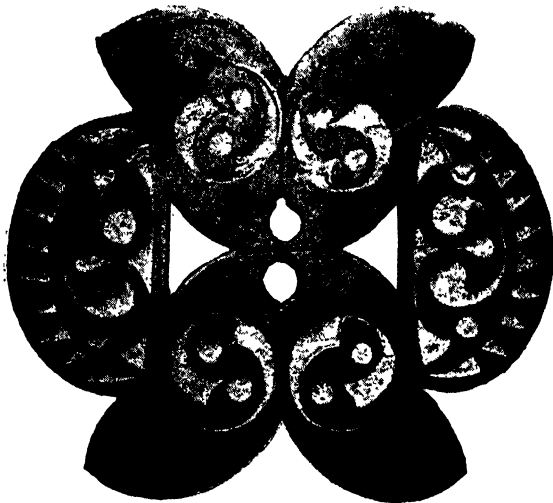


FIG. 4.—Bronze and Enamel Harness Trapping. Early British. Found at Polden Hill, Somerset.

of execution entirely lacking in the thin wire cloisonné work characteristic of the Eastern craftsmen. This example* (Fig. 4) is part probably of a harness trapping and was found at Polden Hill, Somerset, and I would like you to compare this with Fig. 5. In addition to harness trappings, Keltic and Anglo-Roman enamels included such personal ornaments as brooches, pins, bracelets, and a variety of little boxes probably intended to contain scents or unguents. According to Philostratos, a Greek writer established in Rome in the early part of the 3rd century, the art was also practised in the Gallo-Roman colonies of Western Gaul. There seems, however, to have been no knowledge of it in Italy and during the wars and invasions which subsequently ravaged Europe the art seems to have died out on the Continent, although it undoubtedly



FIG. 5.—Pocket Reliquary. Byzantine, 12th century. Cloisonné Enamel on Gold.

survived in England and Ireland: the beautiful Ardagh and Tassilio chalices bear typically Irish characteristics, and the date 758-781 is one of the earliest for enamels bearing figure subjects, and as far as we know these are among the earliest examples of enamel applied to purely ecclesiastical articles. A little later on, the rings of Ethelwulf and Ethelwith, 836-838, and another of the late Saxon period, with an engraved and enamelled inscription and geometrical ornamentation, have characteristics quite distinct from the schools of either Byzantium or Limoges. These three rings are in the British Museum, as are many examples of the Anglo-Roman period to which I have already referred.

On the Continent of Europe the art revived in about the ninth century at Byzantium, then the seat of most of the arts, and our museums possess several good examples of Byzantine craftsmanship.* Fig. 5 shows a pocket

* Reproduced by kind permission of the Trustees of the British Museum.

reliquiary of the 12th century notable for the technical perfection of its workmanship. It is about two inches in diameter and is made of nearly pure gold. The cloisons show very distinctly, and when the minuteness of the detail and the softness of the material are borne in mind one can but wonder at the skill and patience required, not only in bending the tiny pieces of flat wire into shape and affixing them to the base, but also in introducing the enamel into the cloisons and polishing the surface smooth without distorting the shapes. I would like you, however, to notice here the difference between this piece and the harness fitting (Fig. 4). In the Keltic piece the broad and varying shaped masses give a freedom and strength of design entirely lacking in the Byzantine work, which in spite of its wonderful technique is cold and flat. From this period enamels become almost entirely ecclesiastic in their character, and a panel of the mid 11th century in the Victoria and Albert Museum, with the figure of a dancing girl, is notable as one of the few secular Byzantine enamels of which we have knowledge.

From about the 12th century the art declined in the East, but had reappeared in the beginning of the 11th century in the West, in Aquitaine, Limoges being the centre from which the art spread throughout France and Germany. Its influence was also felt in England and Italy, although in the former country the Keltic influence was never lost and in the latter the Byzantine or Greek influence was predominant. Champlevé had been practised in their later period by the Byzantines, first in conjunction with cloisonné, then independently, and was employed exclusively by the early Limoges school. The art found staunch supporters in such ecclesiastics as Suger, Abbot of St. Denis (died 1152), and was strengthened by the religious direction acquired by the Crusaders in the East, while a simple monk, Theophilus, himself no mean craftsman, wrote a treatise on the industrial arts of his time. There is a translation in the British Museum which is not only very interesting to the general reader, but might in these days of specialisation and mass production, be profitably studied by the craftsman, especially if of the younger generation. A very good example of the Limoges work in champlevé can be seen in Westminster Abbey. This is the cushion and sword-belt on the effigy of William de Valence. The date is about 1307.

An earlier example of English figure work in champlevé is a plaque (Fig. 6)† "St. Paul arguing with the Jews and Greeks," and is notable for its character and force. It is one of a series evidently by the same hand, "St. Paul being lowered from the walls of Damascus," in the Victoria and Albert Museum; "St. James the Less and St. Jude," in the British Museum; "St. Paul and his disciples," in the Metropolitan Museum, New York; and "St. Peter essaying to walk on the waves," in the Germania Museum, Nuremberg. The drawing, technique, and, in fact, the whole conception of these pieces is far superior to the German or even French work of the 12th century.

† Reproduced by kind permission of the Director of the Victoria and Albert Museum.

- An altar cross by Godefroi de Clair of Huy on the Maas, about 1165 (Victoria and Albert Museum), shows a typical method of mounting small enamels on a wood base.

A very beautiful example of Rhenish Byzantine work of the 13th century is a shrine or reliquary, in the form of a domed temple (Victoria and Albert Museum) ; practically the whole of the metal work is decorated with Champlevé enamel and the niches are filled with statuettes carved in walrus tusks. A very interesting piece of English enamel is the brass of Sir John D'Abernon at Stoke D'Abernon ; the date is 1277, which is the earliest known enamelled brass in England. The enamelled portions are separate pieces let into the main brass. Somewhat later examples of English Champlevé enamels are the shields on the tomb of Edward the Black Prince at Canterbury, and the " Bruce horn " has also enamels typical of the period.

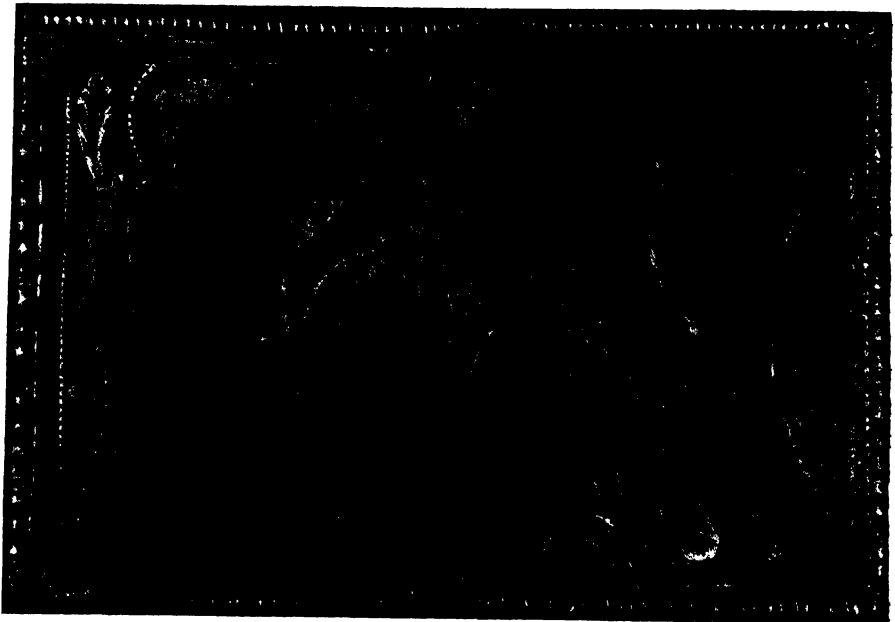


Fig. 6.—Plaque. English, 12th century. Champlevé Enamel on Bronze.

In the pastoral staff of William of Wykeham, Bishop of Winchester (1367), which is preserved at New College, Oxford, we have one of the earliest examples of a fresh type of enamelling known as *basse taille*. In this style the design is carved in the metal in low relief and flooded with transparent enamels ; the effect of this when skilfully executed is very beautiful. This type of work was extensively practised by the Italians, and has been referred to by many contemporary Italian writers as enamel painting—quite a misnomer, and a good example of the errors which arise when otherwise learned people write on a subject of which they have no practical knowledge.

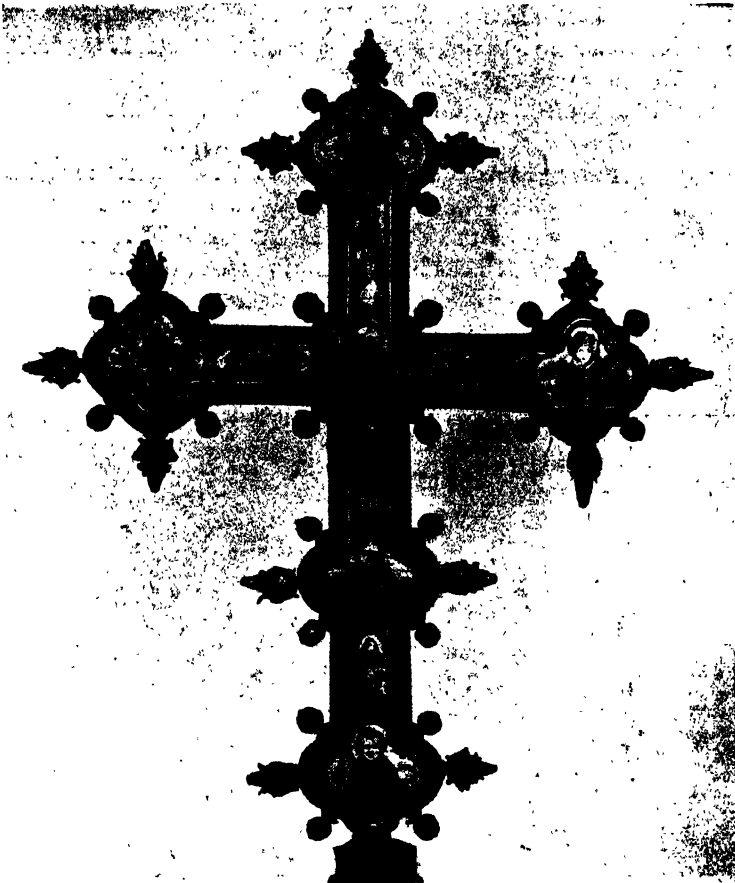


FIG. 7.—Altar Cross. Italian Sienese. 15th century. Inset with Basse-taille Enamels on Silver.

Fig. 7† shows an altar cross, Italian Sienese of the 15th century, also in basse taille. The panels unfortunately are not very distinct, but enamels, unless the colours are virtually flat, are very difficult to photograph. A piece of work made probably early in the 15th century of particular interest to Londoners is the chain of office worn by our Lord Mayor.

Early in the 15th century when Champlevé enamels were beginning to go out of fashion on the Continent, another and very distinctive style was evolved by the enamellers of Limoges. At first this took the form of simple panels or insets, but very shortly entire articles, caskets, bowls, ewers, dishes, etc., were enamelled in their entirety. Comparatively thin copper was employed in making these articles, which were enamelled both back and front, or inside and outside with a dark colour, blue, brown or black, and the design was then partly painted, partly modelled with a semi-transparent white, the result

† Reproduced by kind permission of the Director of the Victoria and Albert Museum.

being that the thickest parts of the white formed the high-lights while the thinner and thinnest parts gave the half-tones and the shadows were formed by the dark background being left bare.

This type of enamelling does not seem to have been practised by the English enamellers, who clung very consistently to *Champlevé*.

Another interesting brass is that of Nicholas Gaynesford and Margaret, his wife, at Carshalton, 1503. The wife's *cotehardi* and skirt retain the original red enamel. The shields in the Henry VII chapel in Westminster Abbey are also of this period and are in wonderful preservation.

As time went on the workers of Limoges, always fine craftsmen, improved both in technique and design. Their work was immensely popular and the best artists of the day did not disdain to supply them with designs. A very beautiful "Head

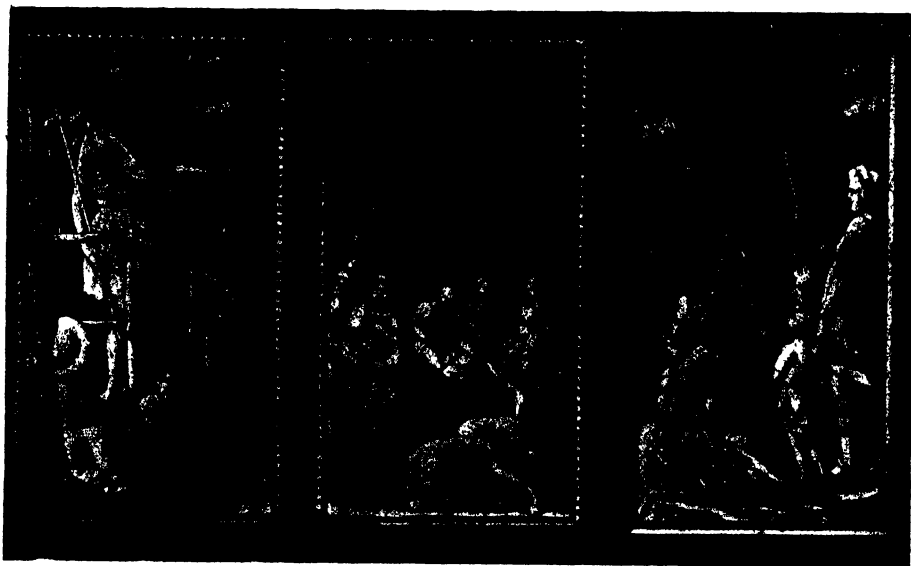


FIG. 8.—Triptych. Limoges (grisaille): By Pierre Raymond, 1560. On Copper.

of Christ" by J. Penicaud, 1550, is in the Victoria and Albert Museum, which also possesses, among many other examples, a triptych (Fig. 8)* by Pierre Raymond, 1560, which personally I consider one of the very finest examples of that type of work. I may mention here that, as in these days, the output from any particular workshop was liable to vary and there are in the Victoria and Albert Museum other examples from the workshop of Pierre Raymond far inferior in workmanship.

When first produced Limoges enamels were in what is known as "*grisaille*," that is, the design was in white on a dark background, and while this particular style remained in vogue throughout the whole period of Limoges work,

* Reproduced by kind permission of the Director of the Victoria and Albert Museum.



FIG. 9.—“Jewel of the Garter.”
English, c. 1640. The centre
group is enamelled “on the
round.” The Garter is Cham-
plevé Enamel. Gold.

modifications were soon devised: first the faces, etc., were tinted flesh colour, then the draperies were coloured by flooding them with pale transparent enamels and, lastly, gold and silver foil were employed; these foils of pure metal were cut to the shape required and applied to the enamel, being kept in place temporarily by means of a little gum water. The articles were then lightly fired and the foils adhered firmly to the enamel, and were then covered with transparent enamels to which they imparted great brilliancy and richness. There are, fortunately for us, many examples of Limoges enamel in our own and other museums and private collections, and it is doubtless due to their being executed on base metal that they have been preserved from the melting-pot, which was, undoubtedly, the fate of many pieces executed on the more precious metals.

Another type of enamelling known sometimes as “translucent in relief” or, more correctly, as “incrusted” is a development of the *basse taille*. In this the design was modelled in comparatively high relief, and the enamel was applied all over, but sufficiently thinly to preserve the general outlines of the relief.

The logical development was to model or cast the design in the round. Fig. 9,† a good example of this, is a jewel of the “Garter,” said to have belonged to Thomas Wentworth, Earl of Strafford, 1640, the centre being executed as just described, while the surrounding garter is in *Champlevé*. Modern collars of the “Garter” are carried out in much the same way. An example

† Reproduced by kind permission of the Director of the Victoria and Albert Museum.

of this collar, together with the Insignia of the other Orders of Chivalry, including the Order of Merit, can be seen in the Regalia room in the Tower of London. These incrustated enamels were very popular as pendants, etc., in Germany and Spain in the 16th and 17th centuries, and there are several fine specimens in the Waddesdon Collection in the British Museum and elsewhere.

The latter part of the 16th century saw a revival, in this country, of enamels for personal use, and there is a very beautiful and interesting example of the work of Nicholas Hilliard, 1580, in the Victoria and Albert Museum. This is a case for a miniature; the front is set with precious stones, while the back and rim are beautifully enamelled in *Champlevé*. There is another such in the Waddesdon Collection, also attributed to Nicholas Hilliard. This is the "Lyte" jewel bequeathed to the nation by the late Baron Rothschild.

From about the 9th century onward, the art, on the Continent, was almost entirely ecclesiastical in its manifestations, and remained so until the beginning of the 17th century. In England, however, a considerable amount of armorial work was enamelled and the art lost its distinctly ecclesiastical characteristics at the time of the Reformation, when, I am afraid, a great deal of beautiful work must have been destroyed by over-zealous iconoclasts.

In the early part of the 17th century painting on enamel was introduced. This style was employed for portraits, allegorical subjects, flowers, etc., on snuff boxes, watch cases, etc., and so closely resembles in its various manifestations the miniature painting on ivory and china painting, with which we are all familiar, that I need say little about it. One of the finest exponents of enamel painting was Petitot, a Genevan, who settled in England for some time, eventually returning to Geneva, where he died in 1691. The full richness yet delicacy of his portraits has never been equalled, though in more modern times Henry Bone, William Bell, and later, John Gillet, another Genevan, ran him very close. The introduction of photography has practically killed the art of portrait painting in enamel, but enamel painting for heraldic and other subjects is still vigorously practised.

From about the 17th century the distinction between the various styles of enamelling which had endured for long periods was no longer so clearly defined the craftsman making use of such combinations of styles as, say, *Champlevé* and *Limoges*, as would best achieve the results he had in view.

The last distinctive type of enamelling is that known as "Battersea," invented by Jenssen about 1750, of which there is a beautiful and representative collection in the Victoria and Albert Museum. Jenssen himself went bankrupt a few years later, and the Battersea works were closed down, but the potteries and Liverpool had taken up the manufacture of these enamels, which continued until the second decade of the nineteenth century, when the vogue died out completely, and has not so far been revived.

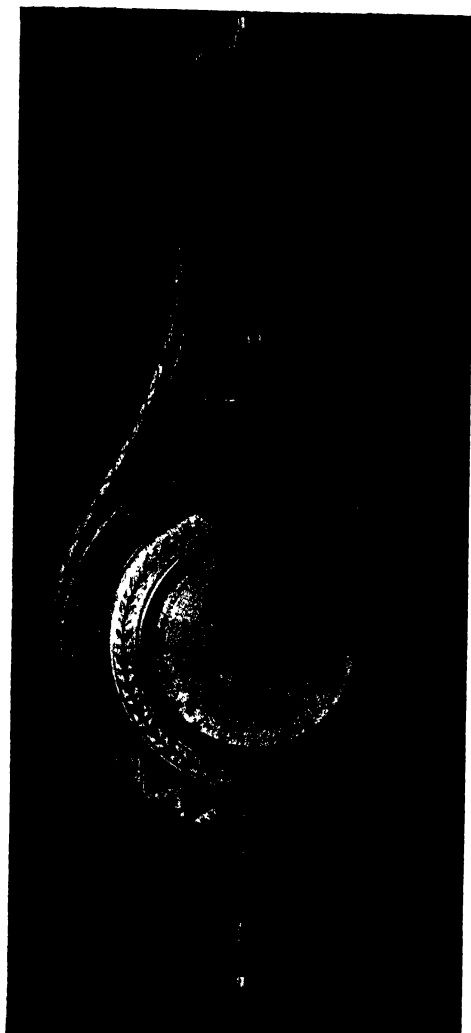


FIG. 10.—Combined Watch and Pedometer.
English, c. 1800. Champlevé Enamel on Gold.

Fig. 10,† a combined watch and pedometer, is a fine example of English craftsmanship, decorated with Champlevé enamel; the date is about 1800.

Fig. 11, a panel for a book cover, gives a fair illustration of a combination of styles. The silver panel was first repousséed and the ground work of certain parts then flat-chased, so that the completed work combines incrustated and basse taille, while the shading of the mantling is enamel painting. This piece is quite modern as is the final illustration, Fig. 12, a bronze altar cross, inset with the "Agnus Dei" and the emblems of the four Evangelists. This

† Reproduced by kind permission of the Director of the Victoria and Albert Museum.

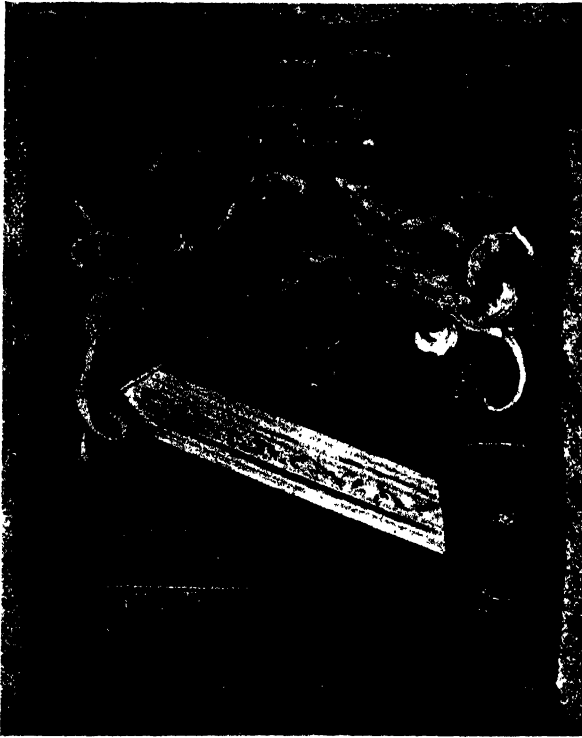


FIG. 11.—Plaque for a Book Cover. English Repoussé Silver. Incrusted Enamel and Enamel Painting. H. de Koningh. 1895.

is one of the few modern English examples in the pure Limoges (Grisaille) style, the figures having been worked up in a semi-transparent white on the dark blue background.

Time has only allowed me to give the briefest outline of the technique and history of the art of enamel, and I have been unable even to touch on the work of the Russians and Scandinavians, or the more distinctive Persian, Indian, Chinese and Japanese enamels, entrancing as the study of these would be, but may I express the hope that, brief as this talk has been, it will have stimulated your interest in enamelling, which, from the variety of which it is capable, the brilliance and richness of its colouring, and, above all, its permanency, should surely rank among the highest of the decorative arts.

Thirty-two slides in all were exhibited in the course of the lecture, but space has only allowed of twelve being reproduced. Most of the others have been referred to in the text, but two, of which the originals were on view, together with several other specimens of modern work, have not been mentioned. These were a silver panel with an achievement of arms in champlevé enamel and a tryptich, bronze gilt with silver panels, in an adaptation of the Limoges style



FIG. 12.—Altar Cross. English. Bronze
inset with Limoges style Enamels on Copper.
H. de Koningh. 1927.

of translucent enamel. Subject, centre, "The Light of the World": wings, Ss. Peter and Paul. These are in the possession of the lecturer, who will be pleased to show them to anyone who may be interested.

DISCUSSION.

THE CHAIRMAN thought Mr. De Koningh had acted wisely in commencing his lecture with a careful definition, because the craft with which he dealt had suffered to some extent from the tyrannous behaviour of words. Someone invented a word to express a certain idea, but in time the meaning changed, and that had happened with regard to the word "enamel." The English word was taken from the French *émail*, which in old French was spelt *esmail* and was connected with the English words "smelt" and "melt." One of the essential ingredients of the

meaning of the word was, therefore, melting or smelting, but to-day the word was used for all sorts of things. Dentists used it for the outer coating on teeth, and it was also used for paint possessing a glossy surface. Unfortunately it had also been employed by antiquarians to describe almost any kind of substance which was applied to metals and other things for their enrichment and colouring. English brasses were not, for the most part, enamelled at all. In a few instances small portions were enamelled and worked into the general scheme, but as a rule the brasses were too large to go into the muffle furnace. He was not sure whether that applied to Continental brasses. Continental brasses were engraved on rectangular plates which were then made up by being placed side by side.

Monumental brasses were supposed to be derived from the more ancient enamels. Champlevé enamels came into use in Europe about the 12th century.

Down to the 11th century enamels were applied to the object they were to decorate in much the same way as jewels; the enamel was applied, as it were, in blobs. As far as he knew there was no special term to describe that method of using blobs of enamel, and he thought it should have some name of its own.

MR. CHARLES FFOULKES, O.B.E., F.S.A. (Curator of the Tower Armouries) said he had come across an instance of Russian enamelling in which the whole of a sword-hilt was covered with a rather crude decoration of yellow and blue. He did not know how it was done.

MR. H. DE KONINGH said the Orientals, and particularly the Chinese, had executed pieces of very considerable size, even larger than a sword-hilt. In the Victoria and Albert Museum there was an ice chest about 4ft. 3ins. long, which was Chinese work, and the whole thing was done in one piece. He had not seen any Russian enamel work of large size, but all the old Russian work he had seen was very crude. For the kind of work they did he did not think it would be difficult to do a sword-hilt.

MR. H. G. MURPHY asked whether it was a fact that brass, as distinct from brasses, could not be enamelled. Some of the work in the Victoria and Albert Museum described as "Chinese brasses" contained what appeared to be black and white enamel.

MR. H. DE KONINGH said it was true that what was ordinarily understood by "brass" could not be enamelled. An alloy of copper containing anything from 30 per cent. of zinc upwards could not be enamelled. The metal used in the "Chinese brasses" was probably not pure copper; it might contain 10 per cent., or perhaps as much as 15 per cent., of alloy, but nothing approaching the amount present in what was usually described as brass.

MR. H. G. MURPHY asked whether it was possible to enamel electrotypes.

MR. H. DE KONINGH said that this was possible. Electrotypes varied. Those he had used were very carefully made with a very slow deposit and a very fine grain. Where that was the case it was perfectly feasible to enamel them.

MR. F. A. PERIGO said that as one who had experimented in enamels, he wished to thank Mr. De Koningh for his informative paper, and also to ask him why he stressed the importance of using plain water. Personally, he had found distilled

water gave better results. It would also interest him to know how many fires were necessary to give a completed result with different enamels, and what the cost per hour of the gas muffles was.

MR. DE KONINGH said he had referred to plain water because if the ordinary supply was reasonably pure there was no reason to use distilled water, but the use of distilled water might lead to slightly better results being obtained. The water obtained from the Metropolitan Water Board was sufficiently pure. If distilled water were to be used all day long he was afraid his clients would refuse to pay the cost. For an ordinary simple piece of work one could not get any degree of finish in less than three fires, and many pieces must of necessity have at least ten or a dozen firings. There was no reason why that should not be done, but to give too many firings was to run the risk of oxidising the alloy.

MR. H. G. MURPHY mentioned that he had fired a piece of enamel more than fifty times without any deterioration of the gold. He thought the whole question depended on the quality of the gold.

MR. DE KONINGH said that with regard to Mr. Perigo's last question, the approximate cost per hour of the gas muffle depended entirely upon the nature of the furnace. Some furnaces were exceedingly wasteful. In the case of the small furnace he had described, which was about five inches across, four inches high and eleven or twelve inches deep, he thought it burned about 60 cubic feet per hour. It was specially constructed, and he doubted whether one would be able to find a furnace on the market which would give the same heat and efficiency for the same amount of gas.

MR. MURPHY said that, roughly speaking, he thought a muffle furnace of that size would cost about 5d. an hour at the average London price of gas, but it depended very much on the type of stove. Some stoves would run away with a lot of gas. One could save gas by boarding the furnace with asbestos boards.

On the motion of the Chairman, a hearty vote of thanks was accorded to Mr. De Koningh for his paper.

MR. DE KONINGH proposed a hearty vote of thanks to the Council of the Royal Society of Arts for allowing him to present his paper, which he hoped had stimulated interest in the subject, and that as a result a craft which had been rather neglected for a considerable time might come into its own once more.

The proceedings then terminated.

OBITUARY.

LIEUT.-COLONEL ALLAN J. C. CUNNINGHAM.—Lieut.-Colonel Allan J. C. Cunningham, who died on February 8th, was elected a Life Member of the Society in 1892. For many years he was a most regular attendant at the meetings, and he very frequently took part in the discussions, his interests and knowledge covering an enormously wide field.

Born in Delhi in 1842, he entered the East India Company's Military Seminary at Addiscombe in 1859, being in one of the last batches of cadets to be trained in that

establishment before it was closed. He passed out first in June, 1860, receiving the Pollock Medal, and was commissioned to the Bengal Engineers, with which Corps he saw active service with the Bhutan Field Force 1865-66, and received the medal with clasp.

His chief appointment in India was Assistant Principal of the Thomason Civil Engineering College at Roorkee, United Provinces, where he was instructor of mathematics from 1871-1881. During this period he conducted hydraulic experiments on the Ganges Canal, the results of which he embodied in a book entitled "Hydraulic Experiments." He returned to England in 1881, and was attached to the School of Military Engineering at Chatham, and again in 1885 when he became Instructor of Construction. After holding the appointments of C.R.E. in Dublin and Shorncliffe, he retired in 1891.

He was awarded the Telford Premium in 1883, and after his retirement devoted his life to the study of Higher Mathematics, his special interest being the Factorisation of High Numbers.

NOTES ON BOOKS.

ENZYMES: PROPERTIES, DISTRIBUTION, METHODS AND APPLICATIONS. By Selman A. Waksman, and Wilburt C. Davison. London: Baillière, Tindall and Cox. 25s. net.

When two men of notable eminence in the field of biological study, like Dr. Waksman of the U.S. Microbiological Department and Dr. Davison of the Johns Hopkins University School of Medicine, co-operate in treating of enzymes in a volume which runs to XII + 364 large octavo pages, the outside world may well awaken to the fact that the enzyme is now to rank alongside the bacterium or other minute organism as a great power for good or evil in social or economic conditions. Inside medical, biological and chemical circles the term enzyme has definitely existed since 1867, when Kuhn "suggested the term enzyme for all unorganised or unformed ferments" (p. 5).

To the book student, the term enzyme will vaguely suggest a substance which is contained in a leaven, barm or yeast, but Kuhn's definition covers a wide range of animal and vegetable products, which induce changes, without themselves being very deeply involved in the ultimately resulting reaction. It may be, however, that all enzymes are cell-products, or in a sense, of microbial origin. Thus, we have on p. 125 a mention of "extra-cellular or exo-enzymes," and on p. 126 we read of "intra-cellular or endo-enzymes."

The authors on p. 7 make a distinction between enzymes and "other catalysts." They say: "The action of an enzyme is specific, each enzyme acting only on substances of definite structure and stereo-chemical configuration, as will be shown later." On p. 7, lower down, we are told that "Enzyme reactions proceed most rapidly at certain definite hydrogen ion concentrations," and this sentiment with numerical data runs through the book, as also does the thermic or energetic aspect; some enzyme reactions being exothermic, others endothermic.

We may confidently say that the most experienced worker in biology or biochemistry will add to his available resources by a study of this monumental work on enzymes. The diction, however, is so lucid, and the system of numerical reference to the quite notable bibliography of 77 pages is so convenient, that even the general reader, with no special knowledge of that which is commonly called science, may

find himself entrapped by new aspects of things ; while the remarkably complete index is likely to lead him into many new paths. Further, there can be very few, if any, manufacturers who cannot profit by a study of the work and by making it accessible to those controlling the factory. In illustration of this wide scope we may refer to p. 259, where section D, " Practical Aspects of Enzyme Activity," commences.

Here we read how diastatic enzymes are made use of in the cotton industry, the stiffly sized warps being " degummed " by enzyme action previously to mercerisation. We need not, however, continue through this section of the book, which any intelligent technician will find rich in suggestion and detail.

The work marks a period in the higher aspects of technical writings, and we heartily congratulate the authors and the publishers.

A DICTIONARY OF MODERN ENGLISH USAGE. By H. W. Fowler. Oxford : at the Clarendon Press ; London : Humphrey Milford. 7s. 6d. net.

The King's English, the joint work of the author of this book and his brother, Francis George Fowler, was recognised immediately on its publication as a standard work of reference and a *sine qua non* for every serious student of the English language. The present volume was planned by the two brothers, but, unfortunately, Francis George Fowler died in 1918 of tuberculosis contracted during service with the B.E.F., and the bulk of the work has been carried out by the survivor.

The dictionary is full of sound and subtle information, and some of the articles are very amusing, as well as informative. In " hackneyed phrases," for instance, the author gives a string of phrases, many of which, though originally good and expressive, have become by mere repetition an offence to the fastidious ear. It will do no one any harm to look down the list and see whether it contains any of his own pet phrases. Probably few people will be able to get to the end with withers unwrung—" Withers unwrung ! " Apprehensively one scans the list to see if this phrase is there. It is not ; but even so one cannot pride oneself on having avoided offence, because the list is prefaced by the warning, " the hackneyed phrases are counted by the hundred, and those registered below are a mere selection."

We doubt if there are any writers of English who avoid all the pitfalls described by Mr. Fowler. Probably the best can learn something from his very careful study of the subject, and if his dictionary induces the ready but often slipshod writer to think twice before he commits himself to paper, it will indeed serve a useful purpose.

THE DICTIONARY OF NATIONAL BIOGRAPHY, 1912-1921. Edited by H. W. C. Davis and J. R. H. Weaver. Oxford University Press. London : Humphrey Milford. 21s. net.

This supplementary volume of the D.N.B. contains the lives of notable persons who died in the years 1912-1921. The period covered by it is over a hundred years, for the late Lord Wemyss was born in 1818, and Francis Bashforth, the mathematician, and Alexander Campbell Fraser, the metaphysical philosopher, in 1819.

No doubt the features in this book which will most strike the public imagination are the lives of those who died in the Great War. Rupert Brooke, the poet, and Henry Moseley, the brilliant physicist, were both cut off in early manhood in the Dardanelles Expedition. The sensations created by the death of Lord Kitchener, Nurse Edith Cavell and Captain Fryatt are not likely to be forgotten by those who were old enough at the time of their occurrence to appreciate their meaning ;

and the extraordinary daring of the Royal Air Force is put on record for ever in the biographies of the three V.C.'s, Albert Ball, William Leefe Robinson, and Reginald Warneford.

The editors of the present volume have fully maintained the splendid traditions of their forerunners, George Smith and Sir Sidney Lee, which long ago established the D.N.B. as an indispensable work of reference.

INDIAN RAILWAYS: RATES AND REGULATIONS. By N. B. Mehta. With an Introduction by W. Tetley Stephenson. London: P. S. King and Son, Ltd. 10s. 6d. net.

Railway problems in the East differ materially from railway questions as affecting Great Britain and Europe. On p. 14 the author tells us that "a cart with its weakened bullocks of a famine year, over roads that are cracked and rutty cannot carry more than one-third of a ton of grains, nor for more than thirteen miles continuously." He then compares this state of things with the facilities now offered by the railways; and in taking a retrospect to 1880, he finds the cost of transport by cart was five times the railway cost, or under famine conditions, ten times.

Relatively to all economic and social matters in India, the very uncertain factor of the famine years has to be taken into account, and the author considers this aspect on p. 99, also on p. 39.

In the book under notice the general question of the working of the railways is introduced by a concise history of origin and early stages, and the book as a whole may be regarded as a plea for railway extension, with development "of a more rigorous yet enlightened policy of state control."

Abundant foot-note references are given to authorities, and the general bibliography (p. 181) adds to the value of the work. The indexing is good and the information in regard to railway legislation on pp. 175-180 is convenient for reference.

GENERAL NOTES.

EXHIBITION OF CONTEMPORARY CULTURE IN CZECHOSLOVAKIA.—An Exhibition of Contemporary Culture will be held in May next at Brno, Czechoslovakia, in which the various Ministries, Local Government Bodies, the Universities, the Teachers' Organisations and private factors in economic life will take part. The special groups will comprise education, the arts, science, literature, industrial art and ethnography. The programme will include big ethnographical, musical and dramatic festivals to illustrate the progress marked of late and especially during the nine years independent existence of the Republic up to now. Great emphasis is being laid upon the practical illustrative qualities of the material exhibited, so that preference is being given to models rather than to diagrams and statistics. Great interest is being shown in this exhibition and many branches of industry are to exhibit special models of their output. Thus, for example, the electrical engineering branch will show a model farm with complete up-to-date electrical equipment. On an area of five thousand square metres, over a hundred home and foreign firms will demonstrate the advantages of electrification for agriculture. Catalogues of the Exhibition will be issued in English, French and German as well as in Czech.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH, BUILDING RESEARCH, REPORT NO. 10: SLAG, COKE BREEZE AND CLINKER AS AGGREGATES.—Breeze and clinker are used extensively as concrete aggregates, but at present there is very little information available regarding the fundamental causes of the failures which are of too frequent occurrence. Such information as is contained in the

literature on the properties of these aggregates and the methods of determining their suitability for building purposes is summarised in the present report. Although scarcely sufficient to permit of definite conclusions it provides some guidance which, owing to the scattered nature of its sources, has probably not before reached the majority of users. Preliminary investigations at the Building Research Station indicate that, in general, the important factor determining the soundness of these materials is the completeness of the combustion of the coal in the furnace. The marked expansion which has been observed in some concretes is attributable to the unburnt coal in clinker and the sulphur content of the material is dependent both on the original coal and the degree and method of combustion. It is hoped that the further experimental work will provide definite information on the properties of clinker and make it possible to evolve reliable tests for its suitability as a concrete aggregate. The report may be obtained, price 9d. net, from H.M. Stationery Office, Adastral House, Kingsway, W.C.2, or through any bookseller.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH. BUILDING SCIENCE ABSTRACTS.—A new monthly publication of interest to all concerned in building construction and allied subjects has recently been placed on sale by H.M. Stationery Office. Its purpose is to provide, for the building industry, up-to-date summaries of the latest developments in the science and practice of building which are taking place throughout the world. Such a service is already provided for the members of other professions by periodicals such as "Biological Abstracts" and "Chemical Abstracts," and the Department of Scientific and Industrial Research has now decided to prepare for general circulation "Building Science Abstracts." This has become possible partly as a result of generous support promised by the Institute of Builders. In this periodical all the more important articles appearing all over the world relating to building will be abstracted by the staff of the Building Research Station at Watford. The enormous literature on the subject and the degree of scientific specialisation which is now essential makes it extremely difficult for any single worker to keep abreast of the whole subject. Only by a scheme of co-operation such as that which the new abstracts will provide can the individual ensure that he misses nothing on the subject in which he may be interested. Some idea of the wealth of printed matter dealing with the building and constructional industries can be gathered from the fact that over 100 different scientific and technical periodicals are being drawn upon regularly in the preparation of the "Abstracts." The "Abstracts" are classified under the following headings: Stone, mineral earths, clay and ceramics; Lime, plaster and chemical compositions in general; Cement and concrete; Metal; Organic building materials; Paint and varnish; Materials in general, their properties and testing; Elements of structures; Housing and domestic engineering; Specialised construction. Within these groups will be found abstracts of papers primarily of interest to the building industry, the teachers of building science and the manufacturers of building materials, while at the end of each section are grouped abstracts of interest chiefly to research workers. These are followed by reference to books and patents. Publication will be monthly, except in August, but a double number (August/September) will appear at the end of September. Subject and name indexes will be issued annually. The subscription rate for the series of eleven monthly issues (including one double number) has been fixed at 10s., post free. Single copies are available, price 9d. each (post free, 10d.). Copies are obtainable by direct application to H.M. Stationery Office, Adastral House, Kingsway, or through a bookseller.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, MARCH 12. Automobile Engineers, Institution of, at the Queen's Hotel, Birmingham. 7 p.m. Mr. G. L. Ensor, "Notes on the Single Sleeve-Valve Principle."

Brewing, Institute of, at Charing Cross Station Hotel, Strand, W.C. 7.45 p.m. Sir E. John Russell, "The Barley Experiments of the Institute's Research Scheme."

East India Association, at Caxton Hall, Westminster, S.W. 3.30 p.m. Lt.-General Sir George MacMunn, "India and Afghanistan."

Geographical Society, Lowther Lodge, Kensington Gore, S.W. 5 p.m. Mr. T. Hay, "Shore Topography of the English Lakes."

Metals, Institute of, at 30, Elmbank Crescent, Glasgow. 7.30 p.m. Annual General Meeting.

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Dr. E. Schrödinger, "Wave Mechanics." (Lecture III).

Transport, Institute of, at the Queen's Hotel, Birmingham. 6 p.m.

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Prince D. S. Minsky, "The Russian Novel after 1880." (Lecture IX).

At University College, Gower Street, W.C. 2 p.m. Dr. Charles J. Sisson, "The Epic of England."

TUESDAY, MARCH 13. Asiatic Society, at Burlington House, W. 4.30 p.m. Prof. Dr. S. H. Langdon, "Results of the Herbert Weld and Field Museum Expedition at Kish (Hursagkalamma), and Jemdet-Nasr."

Anthropological Institute, 52, Upper Bedford Place, W.C. 8.30 p.m. Prof. E. H. L. Schwarz, "Bush-Man Types."

Illuminating Engineering Society, at the Holophane Company, Elverton Street, Westminster, S.W. 6.30 p.m. Dr. S. English, "The Manufacture and Properties of Glass and their Application to Illuminating Engineering."

Petroleum Technologists, Institution of, at the Royal Society of Arts, Adelphi, W.C. 5.30 p.m. Lt.-Col. S. J. M. Auld, D.Sc., "The Natural Gas of South Persia, Process Development, and Exploitation."

Photographic Society, 35, Russell Square, W.C. 7 p.m. Annual General Meeting.

Quekett Microscopical Club, 11, Chandos Street, W. 7.30 p.m. Mr. T. H. Savory, "Spiders and their Environment."

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Prof. J. S. Huxley, "The Behaviour of Animals." (Lecture IV).

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Sir Bernard Pares, "Russian History from Peter the Great to 1861." (Lecture VIII).

At the London School of Economics, Houghton Street, W.C. 5 p.m. Prof. Werner Sombart, "The History of Capitalism." (Lecture I).

At the National History Museum, South Kensington, S.W. 5.15 p.m. Mr. J. Ramsbottom, "The Evolution and Classification of Fungi." (Lecture II).

At University College, Gower Street, W.C. 5.30 p.m. Prof. Dr. J. G. Robertson, "Henrik Ibsen." (Lecture III).

WEDNESDAY, MARCH 14. Civil Engineers, Institution of, Great George Street, S.W. 6.30 p.m. Mr. H. M. Pearson, "The Belgian Railways."

Fuel, Institute of, at Burlington House, W. 6 p.m.

Metals, Institute of, at the Applied Science Department, University of Sheffield. 7.30 p.m. Conjoint Meeting with kindred Societies. (Electrical Engineering Lecture).

Public Health, Royal Institute of, 37, Russell Square, W.C. 4.30 p.m. Dr. Robert Donaldson, "Bacteriology in its connection with Forensic Medicine."

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Dr. E. Schrödinger, "Wave Mechanics." (Lecture IV).

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. Otakar Vocadlo, "The Modern Czech Theatre." (Lecture II). At King's College, Strand, W.C. 5.30 p.m. The Hon. Mr. Justice Sankey, "Principles and Practice of the Law To-day."

At the School of Oriental Studies, Finsbury Circus, E.C. 5.15 p.m. Prof. Alice Werner, "Rider Haggard and Africa."

THURSDAY, MARCH 15. Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m. Dr. Rudolf, "Testing of Materials used in Aircraft Construction."

Chemical Society, Burlington House, W. 8 p.m. (1) Messrs. H. Burton and C. K. Ingold, "Mobile-anion tautomerism. Part I. A preliminary study of the conditions of activation of the three-carbon system, and a discussion of the results in relation to the modes of addition to conjugated systems." (2) Messrs. T. M. Lowry, C. A. H. MacConkey and H. Burgess, "Studies of dynamid isomerism. Part XXVII. The absorption-spectra of prototropic compounds. Physical properties of the enolic and ketonic forms of benzoylcampbor." (3) Messrs. J. J. Etridge and S. Sugden, "The parachor and chemical constitution. Part IX. Boron compounds." (4) Mr. E. S. Hedges, "Observations on the passivity of metals."

Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m.

Linnean Society, Burlington House, W. 5 p.m. L.C.C., The Geffrye Museum, Kingsland Road, E. Mr. E. R. Gribble, "The Advantages of Antique Furniture."

Mechanical Engineers, Institution of, at the Hotel Metropole, Leeds. 7.30 p.m. Informal Discussion on "Payment by Results."

Metals, Institute of, at 83, Pall Mall, S.W. 7.30 p.m. Mr. Wesley Lambert, "High Tensile Bronze."

Royal Society, Burlington House, W. 4.30 p.m.

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Dr. J. J. Fox, "Optics and Chemistry." (Lecture II).

Tropical Medicine and Hygiene, Royal Society of, at the Royal Army Medical College, Millbank, S.W. 8.15 p.m.

University of London, at the London School of Economics Houghton Street, W.C. 5 p.m. Prof. Werner Sombart, "The History of Capitalism." (Lecture II).

FRIDAY, MARCH 16. Dyers and Colourists, Society of, at Milton Hall, Manchester. 7.30 p.m.

London Society, at the Royal Society of Arts, Adelphi, W.C. 5 p.m. The Rev. Father W. J. Wood, "Westminster Cathedral."

Mechanical Engineers, Institution of, Storey's Gate, S.W. 6 p.m. Captain H. P. M. Beames, "The Reorganization of Crewe Locomotive Works."

Photographic Society, 35, Russell Square, W.C. 7 p.m. Meeting of Pictorial Group.

Royal Institution, 21, Albemarle Street, W. 9 p.m. Prof. E. T. Whittaker, "The Quantum and Relativity Theories of Light."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Mr. Julian Krzyzanowski, "Polish Literature." (Lecture VIII).

At King's College, Strand, W.C. 5.30 p.m. Mr. Sidney Smith, "Babylonian Sculpture."

5.30 p.m. Miss Enid Welsford, "Troilus and Cressida." At University College, Gower Street, W.C. 5 p.m. Mr. C. T. A. Pantin, "Comparative Physiology." (Lecture X).

SATURDAY, MARCH 17. L.C.C., The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Mr. H. Harcourt, "Food and Famines in India."

Royal Institution, 21, Albemarle Street, W. 3 p.m. Sir Ernest Rutherford, "The Transformation of Matter." (Lecture II).

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK

WEDNESDAY, MARCH 21st, at 8 p.m. (Ordinary Meeting.) LIEUT.-COMMANDER RUPERT T. GOULD, R.N. (ret'd.), "The Modern Typewriter and its Probable Future Development." COL. SIR HENRY LYONS, D.Sc., F.R.S., will preside.

FIFTEENTH ORDINARY MEETING.

WEDNESDAY, MARCH 7th, 1928. SIR FRANK WATSON DYSON, K.B.E., LL.D., D.Sc., F.R.S., Astronomer Royal, in the Chair.

The Trueman Wood Lecture on "Some Wider Problems of Cosmogony" was delivered by Dr. JAMES HOPWOOD JEANS, M.A., D.Sc., LL.D., F.R.S. The lecture will be published in the *Journal* dated May 11th.

INDIAN SECTION.

FRIDAY, MARCH 9th, 1928. COL. THE MASTER OF SEMPILL in the Chair.

A paper on "The Air Routes of India" was read by LIEUT.-COL. I. A. E. EDWARDS, C.M.G., Chief Technical Adviser, Department of Civil Aviation, Air Ministry. The paper and discussion will be published in the *Journal* dated May 18th.

THE ALBERT MEDAL.

The Council will proceed to consider the award of the Albert Medal of the Royal Society of Arts for 1928 early in May next, and they therefore invite Fellows of the Society to forward to the Secretary on or before Saturday, March 24th, the names of such men of high distinction as they may think worthy of this honour. The medal was struck to reward "distinguished merit in promoting Arts, Manufactures and Commerce."

A list of those who have received the medal since its institution in 1864 was printed in the last number of the *Journal*.

PROCEEDINGS OF THE SOCIETY.

DOMINIONS AND COLONIES SECTION.

TUESDAY, JANUARY 31ST, 1928.

LIEUT.-COL. SIR ARCHIBALD WEIGALL, K.C.M.G., in the Chair.

THE CHAIRMAN, in introducing Lord Lovat, said that he was particularly qualified to deal with his subject, not only on account of his distinguished personal career, but from the dual official position he now held as Parliamentary Under-Secretary of State for Dominion Affairs and as Chairman of the Oversea Settlement Committee. He had thus an unrivalled knowledge on the subject of Empire migration.

The following paper was then read :—

MIGRATION IN THE EMPIRE.

By THE RIGHT HON. LORD LOVAT, K.T., K.C.M.G., K.C.V.O., C.B., D.S.O.,

Parliamentary Under-Secretary of State for Dominion Affairs, and
Chairman, Oversea Settlement Committee.

I. HISTORICAL.

Emigration in the present sense of the word from this country may be said to have begun in the early part of the 17th century, and Virginia, Massachusetts, Bermuda and Barbados were the fields in which our first successful attempts at colonisation were made.

The modern history of migration from the British Isles began at the close of the Napoleonic Wars. For some years our population had been growing rapidly, and at the end of the war there was an increasing amount of pauperism and distress. It was felt that a system of State-aided migration would provide the best means of meeting the situation. Money was accordingly voted by Parliament to assist emigration both to Canada and to the Cape of Good Hope, and subsequently, as a result of the efforts of Gibbon Wakefield, a colonisation society was formed in 1830, and an Emigration Commission appointed by the Government in 1831. From the activities of these organisations began the first settlements of Australia and New Zealand.

In 1878 the Government Emigration Commission died out as a separate body, and its remaining functions were transferred to the Board of Trade. From that time until the time of the Great War the interest which His Majesty's Government took in the movement of its citizens to other parts of the Empire or to foreign countries was confined to the support of an office, known as the Emigrants' Information Office, established in 1886 for the purpose of furnishing authentic information to enquirers with regard to conditions overseas. His Majesty's Government undertook no responsibility, either in the matter of

granting assistance or in that of directing migration to the British Dominions rather than to foreign countries. The only assistance a migrant could obtain was from some of the overseas Governments who granted assisted passages to certain classes of settlers.

During the last ten years this policy has undergone a complete change, until to-day His Majesty's Government in co-operation with the Dominions is engaged in the task of giving a large measure of financial assistance towards migration and directing the outflow of people from this country to other parts of the Empire. The first indications of this change are to be found in the report of the Dominions Royal Commission, which was appointed in 1909 to enquire into the development of the natural resources of the Empire and which reported in 1917. The Commission were impressed by the resources of the Dominions, but realised that man-power was essential to their development. At the same time, they felt that this increased man-power should, as far as possible, be drawn from the United Kingdom. The Commission, therefore urged the need for a more effective supervision and direction of migration by co-operation between the Home Government and the Dominions, and recommended the establishment of a Central Authority.

After the War, it became obvious that many problems connected with migration were bound to arise, and the Oversea Settlement Committee was appointed to advise the Government on the subject. The first step in the direction of State-aided migration was taken in 1919, when, upon the recommendation of the Oversea Settlement Committee, free passages were granted at the expense of His Majesty's Government to approved ex-Service men and women and their dependents who desired to settle in some other part of the Empire. The scheme was finally closed at the end of 1922, by which date free passages had been granted to some 82,000 souls. The great majority of these people were able to settle satisfactorily overseas.

In 1921 a Conference of Prime Ministers of the Empire took place for the purpose of considering the possibilities of State-aided settlement within the Empire, and this Conference recommended co-operation between His Majesty's Governments in Great Britain and the Dominions, both financially and in all other respects, in a comprehensive policy of Empire land settlement and Empire directed migration. The Conference expressed the hope that the Government in this country would secure the powers necessary for carrying out its part in schemes of co-operation, preferably in the form of an Act, which would make it clear that the new policy was intended to be permanent.

In pursuance of this recommendation, the Empire Settlement Act was passed in 1922, and this Act forms the basis of the present policy of State-aided Empire Settlement. The Act, which is to be in force for a period of fifteen years, i.e., until May 31st, 1937, empowers His Majesty's Government to co-operate with the Government of an overseas Dominion or with an approved public or private organisation in this country or overseas in financing schemes

for assisting the settlement in the oversea Dominions of suitable persons from the United Kingdom. The contribution of His Majesty's Government is not to exceed half of the total cost of any scheme, and the maximum expenditure under the Act in any one year is limited to £3,000,000.

The Act indicates the intention of the Home Government to adopt a continuous policy on the matter of oversea settlement and its willingness to co-operate financially in any scheme calculated to further this object.

II. POLICY.

The object of the present policy of oversea settlement is to distribute the white population of the British Commonwealth in the most efficient manner as between all its parts. It is not a temporary policy for dealing with depressed industrial conditions in this country. There is no doubt as to the desirability of a more effective distribution of the white population of the Empire. In this country the population is congested. Some people would say unduly congested. In the Dominions there is no doubt that there is ample room for many times the existing population, and unless the empty spaces are filled by people of British stock, they will be filled by alien people from other parts of the world. At the same time, the fulfilment of this policy should do much to stabilise industrial conditions both at home and overseas by a proper distribution of our manpower and a fuller development of all our resources. The essential need of the oversea Dominions for an increase of population to develop their resources and the desire that this increase should be effected by means of British stock are the objectives on which all are agreed.

The problem of the distribution of population is far from simple if it is to be carried out on a proper scientific basis. A hundred years ago when, after the Napoleonic Wars, a policy of State-aided oversea settlement was adopted, the problem was comparatively simple. The Mother Country had the entire control of the "Colonies," and was able to pay the passages of persons wishing to go overseas and to give them free grants of land. This led to movements which laid the first foundations of the great Dominions of Canada, Australia, New Zealand and South Africa. But the "Colonies" have now become self-governing nations and naturally claim the final decision as to the new settlers they are to receive. Any policy, therefore, having as its object the transfer of population from this country to the Dominions is one which calls for the closest co-operation between the Home Government and the Governments of the Dominions. It is often suggested that the best way of dealing with this problem would be by the wholesale transfer of large bodies of migrants from this country to empty spaces in the Dominions, and for the creation of great irrigation or dry farming schemes. No such rough and ready solution of the problem is, however, practicable.

A moment's thought will show that it would be inadvisable for the Home Government to acquire great tracts of land in an area outside its own juris-

diction. It would be unpractical to invest large sums of money in mass farming or irrigation schemes at a distance of many thousand miles from the Home Country. Land settlement schemes are notoriously difficult to administer. The margin between success and failure is small. Local experience and attention to a thousand and one details are essential to success.

A good deal can be done by Government intervention to overcome some of the difficulties. Avenues of development can be explored and capital can be made available for schemes which are really sound. Assistance can be given to suitable persons to enable them to make the journey and take advantage of the opportunities which offer overseas. Arrangements can be made for providing short preparatory courses in this country which will adapt intending settlers to the conditions which they will have to face in the Dominions. In these ways a larger flow of people can be stimulated than would take place if the movement were left to itself at a time when we have not yet recovered economically from the effects of the Great War. But the State cannot do everything. It cannot create the will to migrate, and the fact that the annual flow of population to the Dominions, in spite of a large increase of State assistance, is still well below pre-war level, has been regarded as indicating a definite lack of desire on the part of our people to go overseas. It would be wrong to suggest, however, that the main difficulty lies in this country—there are conditions overseas which are to a large extent responsible for the slow rate at which the population of the Dominions is being increased by means of overseas settlement.

Before the War the flow of population from this country to the overseas Dominions averaged 200,000 per annum. Since the War it has not approached that figure, in spite of an immediate surplus of population in this country and of the very liberal assistance which has been granted by the Governments concerned towards the cost of passages. The causes for this falling off (or at any rate absence of increase) in migration are various, but it is sufficient here to refer to what are generally considered to be the two prime causes:—

- (a) bad trade conditions both here and overseas, and
- (b) the restrictions which the Governments of the Dominions find it necessary to place on the classes of persons to whom assisted passages can be granted.

As regards the first of these causes, it appears to be established that there is a close relation between industrial prosperity or depression and the movement of population. Migration figures are highest when trade is good and lowest when bad trade conditions prevail. The principal reason for this is that prosperity at home usually coincides with prosperity abroad. Thus, in good times the individual is able to accumulate a little capital which endows him with the necessary confidence and with the necessary means to launch out for himself upon a new life overseas, whilst prosperity overseas means that more numerous and more varied openings are available for newcomers.

As regards the second cause, depressed industrial conditions have prevailed generally of recent years both here and in the Dominions, where capital for development purposes has been lacking. The demand for labour overseas has been confined practically to agriculture and its allied industries. Thus the absorptive capacity of the Dominions has been limited, and this has made it necessary for the oversea Governments to place restrictions on the classes of migrants to whom assisted passages could be given.

III. SCHEMES UNDER THE EMPIRE SETTLEMENT ACT.

Of the work under the Empire Settlement Act, I will only deal to-night with—

- (1) facilities for transport,
- (2) agricultural schemes,
- (3) development schemes,
- (4) training schemes.

(1) *Facilities for Transport.*

Work under this head has led to the cheapening of passage rates in the case of those persons who can be absorbed readily by the Dominions. These cheaper fares provide a bridge by which suitable people from this country can take advantage of the opportunities which offer in Canada, Australia, New Zealand and Southern Rhodesia. Under the Assisted Passage Schemes which have been arranged in co-operation with the oversea Governments under the Empire Settlement Act, migrants can go to Canada for from £2 to £8, according to their destination, instead of the ordinary fare of from £18 to £30, whilst children can travel free. The passage rate to Australia for adults is £16 10s. od. for single persons, and £11 each for married persons, with further reductions in the case of young persons under 19 years of age, while domestic servants and children under 12 receive free passages. To New Zealand the cost of passage for all persons over 19 years of age is now £11, except in the case of girls and single women, who receive free passages, while all persons under 19 proceed free of cost. In the case of Southern Rhodesia, liberal grants are made towards the cost of the journey of approved settlers.

(2) *Agricultural Schemes.*

Schemes have been arranged under the Empire Settlement Act to facilitate the settlement upon the land overseas of persons from this country. In Canada, a scheme known as the 3,000 Families Scheme is now approaching completion. Under this scheme nearly 3,000 British families have been settled on prepared farms in the Dominion with a remarkable degree of success. The Dominion Government provides the farm and the Home Government advances £300 per settler for stock and equipment. New schemes have been

arranged with a view to enabling this movement to be continued. Other schemes with Governments and private companies have been and are under discussion.

In Australia, a valuable and, on the whole, successful experiment was made in Western Australia for the settlement of British families in groups on virgin land. Some 1,600 families from this country have been settled under this scheme, which, however, has proved much more costly than was anticipated, and has had for this reason to be closed to new settlers pending an examination of the financial position.

The criticism is sometimes made that more should be done in the way of land settlement schemes. It must be remembered, firstly, that land settlement schemes are costly, and, including transport, training, etc., average something in the neighbourhood of £500 per family; and secondly, unless done under the best possible auspices, do not always lead to success. The failure of individuals, often through their own fault, sometimes through the fault of the scheme, does untold harm to the general question of migration.

(3) *Development Schemes.*

In 1925 His Majesty's Government and the Commonwealth Government of Australia entered into an Agreement, under which the Commonwealth Government agreed to raise loans for the purpose of making advances up to £34,000,000, at a low rate of interest, to the State Governments for expenditure upon approved schemes of settlement and development. His Majesty's Government contribute £150,000 for every £750,000 of loan issued by the Commonwealth to the States. There is no doubt that if development is to take place in Australia, new capital must be invested in the country, and this Agreement gives an opportunity for providing that capital to the various State Governments at a most advantageous rate. A number of undertakings, including land and irrigation schemes, have been proposed under this Agreement, and the Commonwealth Government have appointed a Development and Migration Commission, one of whose duties is to advise the Commonwealth Government as to the allocation of loan money to be devoted to development or migration.

Special attention has been paid to the encouragement of the migration of juveniles both in the direction of giving specially reduced, or free, passages, and also in the arrangement of special schemes for the placing and welfare of boys overseas, either under the auspices of the Dominion Governments or of recognised societies approved by the Governments concerned. These schemes sometimes take the form of apprenticeship schemes, whilst in others the boys remain under the care of a recognised society until they reach the age of 18 years, being regularly visited during that period by representatives of the society and of the oversea Government.

(4) Training.

Attention has been given to the question of preparing settlers for settlement overseas by the provision of courses of training or testing in farm work in this country. There are many persons who, after consideration of the possibility of oversea settlement, decide that they are not qualified to take the venture. It helps these people to make up their minds if centres are available in this country where they can be given some idea of the conditions under which they would be expected to work overseas. The number of accepted migrants is increased, and many who would otherwise prove unsuitable can be eliminated. The Ministry of Labour, in co-operation with the Oversea Settlement Committee has established two centres for providing training courses to single men, and other training farms for men have been established by private organisations in co-operation with the Committee. The Army Training Centre at Chiseldon, under the effective leadership of Major Stibbard, will train soldiers as well as civilians for settlement overseas.

Training for Women.

Women are trained for household work in Australia under the scheme at Market Harborough, in which the Australian Government shares in the expenditure. The centre, which was recently opened by the Duchess of York, can accommodate 40 girls at a time. The length of the course is three months.

Boys' Training.

A number of societies, e.g., the Salvation Army and the Church Army, have training centres for boys, in the cost of which the Oversea Settlement Committee share.

A new development which is regarded as most hopeful is the new training centre at Newcastle. This establishment is run under the auspices of municipal authorities and with the co-operation of the Oversea Settlement Committee. The boys are trained on farms in the neighbourhood of the hostel. They are also taught some elementary carpentry, the repair of boots and household work. The Miners' Welfare Fund subscribes for those boys who are unemployed sons of miners. The scheme is nearly self-supporting, and has aroused considerable interest in many localities, and it is hoped that similar centres will be established elsewhere.

The interest of the Government in oversea settlement covers a wider field than the simple grant of assistance, whether towards passages or to schemes for the settlement of persons on the land overseas. The matter of the arrangements for the reception and welfare of settlers after arrival overseas is one of the utmost importance, and great improvements have been effected in this direction during the past few years. In this work, in which a human link is invaluable, the Governments concerned have the assistance of the numerous voluntary organisations both in this country and overseas who interest them-

selves in the welfare of the new settlers. In this work the part which the Churches can play is invaluable.

IV. CONCLUSION.

Whilst the results which have attended the working of the Empire Settlement Act may from point of view of numbers be regarded in some quarters as not entirely satisfactory, it may be mentioned that since the Oversea Settlement Committee was established in 1919, nearly 350,000 approved settlers have been assisted by the Governments concerned to proceed to other parts of the Empire. Moreover, from the broader point of view of the future of the Empire as a whole, its effect has been most valuable. The loans, the assisted passages, the grants for training, the assistance to voluntary societies, are evidence of the desire of His Majesty's Government to co-operate in the development of the overseas Dominions. It is an indication of the unity of the Empire, and it has played a prominent part in the development of the conception of the Empire as a great Commonwealth of British peoples.

It would be idle, however, to ignore the difficulties which confront us in dealing with this problem. Some of these I have already touched upon. But one of the greatest difficulties to be overcome is the increase of the urban and the decrease of the rural population in this country, and, to a lesser extent, in the Dominions themselves. The result is that large sections of the population are becoming increasingly disinclined to the routine of country life and, perhaps, less adaptable and less fitted for a life on the land in the Dominions than were their fathers. In the Dominions, the drift to the cities has the further effect of increasing the political influence of the towns, and the natural desire of the town-dwellers to safeguard their own standards of living results in an attitude of hostility towards any form of assisted immigration other than for work in primary industries. The result is that the main openings for our people overseas are on the land. Although the land offers its rewards in the shape of independence and farm ownership for those who qualify by intelligence, thrift and industry, there is no doubt that the numbers of our people who are *prima facie* suited to such a life are limited, and, in addition, work upon the land is heavy work, and for the worker—except that as a farmer he is his own master—the return is often poor as compared with the industrial worker in the towns. The door is open into the Dominions, of course, for all classes of workers from this country who can pay their own passages, but, as I have already pointed out, the high cost of passages severely restricts the number of those who can go overseas without assistance. If the door could be open wider for those travelling under "assisted passages" from this country, there would be a large increase in the numbers going overseas. The difficulties with which the Oversea Governments are confronted are fully realised, but my own personal feeling is that the future possibilities of the Dominions are so enormous that they could with confidence remove some of the existing

restrictions. There is a tendency to look at this problem as one which primarily concerns this country, and to ignore the vital necessity in the interests of the Dominions themselves of an increase in their manpower. Both from the point of view of the development of their natural resources and for their future security increased population is essential. At the same time, I agree with the Australian Commonwealth statistician when he says: "Mere talk of empty spaces here and surplus population there will relieve the situation nowhere, and mere transference of the surplus population to the empty spaces without adequate consideration of the ability of the empty spaces to sustain the surplus population will accentuate and not alleviate existing difficulties."

I have not said enough about the valuable work of the Associations that work with us and of the voluntary societies abroad who assist us, because it is very difficult to do so without going too much into detail, but I should like to say how impressed the Committee is with the value of this work. We believe that the voluntary societies will, in the long run, take over the work that we have to do; and the more that is the case, the better we shall be pleased.

Our Empire has been built up on voluntary effort, and we believe in voluntary effort to the greatest degree possible. We believe that the voluntary societies have got infinitely greater power than any Government organisation in regard to the most important matter of all, the nominated passages which we can offer. The nomination of individuals is one of the most important lines of migration, and the nominated passages have the advantage that the individual passes from a home to a home, and that eliminates a great deal of the risk inherent in any Government-aided scheme. If I have not said much about the work of voluntary societies it is not because I do not realise their value.

DISCUSSION.

THE CHAIRMAN said he could not criticise Lord Lovat's admirable paper, but could only commend it. Personally, he was present that afternoon in the Chair as a substitute for his friend Lord Clarendon, who was prevented by illness from attending. His only claim to deputise for Lord Clarendon was that he had the privilege of presiding over the "Omnibus" Committee which was composed of representatives of 36 voluntary Societies in this country engaged on migration work. That Committee was convened by the Royal Colonial Institute, and had the additional advantage of direct liaison with the Oversea Settlement Committee by having attached to it the Secretary of that Committee. Any views he might express, however, must be taken as being his own and not those of the Committee.

The dominating fact brought home by Lord Lovat's paper was that the power of absorption at the circumference was all important. From his own experience in Australia, and on the Committee to which he had referred, he had come to the conclusion that both in official and voluntary circles there was a good deal of misconception as to the outlook, aims and aspirations of a country like Australia. Australia—to take that country as an example—had a soul, a nationhood, but also inevitably the outlook of a young country, wedded to British traditions but invigorating and vitalising those traditions, and with an indefinable national outlook which it was very hard for people in this country to realise.

As Lord Lovat said, really efficient work could be done voluntarily far more effectively than by Governments. One might be asked what could be done to weld together the two different outlooks on social, political and economic questions. He would venture to offer two suggestions. One was a suggestion which, when in a position of more responsibility and less freedom, he had made officially. It appeared to him that some interchange of the younger Civil Servants between Australia and this country would be desirable, whereby young Civil Servants here should spend two years in Australia and *vice versa*. Given that interchange, one would get an amalgamation of the two atmospheres to a certain extent, and nothing but good could follow. That had a considerable bearing on the question of migration.

His second suggestion was this. Although in his official hours and in the Cabinet room it was impossible for a Governor sent out from home to do other than maintain a strictly constitutional attitude towards the Ministers who advised him, it was possible in unofficial conversations to try to bring the outlook of this country before individual Ministers in Australia, and so bring it in contact with the younger outlook of Australia.

He took a great interest in what was known as the "Big Brother Movement." That was a most democratic movement. It passed through a very close sieve, from the point of view of physique, intellectual equipment and moral character, the boys who were selected to be sent out, and when they got out to the Dominion there was a "big brother" to look after them. The parents at this end could, therefore, be convinced that even 12,000 miles away the boys would have *in loco parentis* some responsible individual to watch their careers.

At the "Omnibus" Committee meetings he had heard hard things said about the Oversea Settlement Committee. It was quite impossible to expect the financial arrangements of the Empire Settlement Act, however, to be altered in such a way as to disturb the even balance of 50/50. 50 per cent. was as much as any House of Commons in this country would allow to be given for any development or migration scheme in a Dominion where the actual expenditure of the money was not controlled from this country. Short of altering the 50/50 basis, however, experience might show that in some respects the provisions of that Act might be modified.

LIEUT.-COL. C. H. E. MANNING, D.S.O., O.B.E. (Director of Migration and Settlement for the Commonwealth of Australia), said he had been very interested in what the Chairman had said with regard to the difference of outlook which certainly existed between the Mother Country and the Dominions. In regard to schemes of migration, Australia, at all events, did not regard Canada, South Africa and New Zealand as competitors in the field; Australia invited them all to co-operate in achieving a movement which seemed as essential to Great Britain as it was certainly necessary for the development of those vast spaces which Australia herself controlled.

Mention had been made of the value of nominations. He cordially agreed with that, because they testified to the success attained by those who had preceded the nominees. In the case of Australia, in 1922 nominated migrants numbered 11,000. That meant that prior to that there must have been a considerable number of successful settlers. For the year ending 31st December, 1927, however, the nominated migrants to Australia numbered over 23,000.

The bulk of those nominations were made by boys who had gone out in the last few years, and even boys of 19 and 20 had nominated their parents and relations to come out. That was a fine tribute to the success of the boy movement. The boy was adaptable; he became rapidly acclimatised, and his own experience in Australia had been that the boy who was most generally successful came from the towns and not from the country districts, possibly because in the towns his intelligence had been.

stimulated by closer contact with other people. It was a fallacy that boys from rural districts necessarily proved the better farmers.

He was in general agreement with all that Lord Lovat had said. People sometimes asked why the Dominions, with their vast vacant areas of land, did not put hundreds and thousands of people on those vacant spaces. To do so, however, would mean starvation for the unfortunates who were placed there. It was sometimes said that in the old days the people were not spoon-fed. People in those days, however, were inured to harder conditions. No humane Government would desire to submit the people of to-day to the struggles and hardships endured by those who went out in the early days. The problem had to be faced from a different angle altogether.

It was the considered opinion of the Development and Migration Commission, which was composed of some of the finest brains in the Commonwealth, that development should run hand in hand with migration, and should in fact precede it. It was essential to develop the vast vacant areas of land before placing people on them, so that the absorption might be gradual and beneficial not only to the State but to the migrants themselves.

There were huge schemes in Australia at the present time for developing the empty spaces. In one State a block of land of 6 million acres had been set apart for the provision of 6,000 1,000-acre farms, 50 per cent. of which under the agreement were to go to migrant families from this country. In South Australia a huge lake was being drained to provide 40,000 acres of most fertile land. In New South Wales 1,000,000 acres of excellent land were to be provided by development schemes. In Queensland two schemes of over 1,000,000 acres were in hand. All that land would be available for settlement, but could not be developed in a few moments. It required time and money, and that was where the British Government had helped the Commonwealth Government. It was essential there should be no dislocation of industry in the States of Australia.

VISCOUNTESS ELIBANK said she was gratified to hear the Market Harborough scheme was going so well, and that the Dominions were now contributing to it. She hoped the Dominions would extend this policy of contributing to schools which gave training in the domestic arts in this country. There should be a 50/50 scheme for teaching women to be good cooks and good servants to go out to the Dominions and Colonies. She had had a great deal to do with hospitality to overseas guests in this country, and they always pleaded that good cooks might be sent to them. She replied that it was for the Dominion to relax their restrictions so as to make it easier to send people there.

There was a great deal of ignorance among girls in this country as to the immigration regulations, and there was a feeling that those regulations were strangling. Some of the restrictions did appear to be strangling, and if they were somewhat relaxed she was sure greater numbers of girls would emigrate.

Failures among emigrants had been referred to, and she would like to instance three examples of success. In one case a very well educated girl with a diploma of physical training went to Australia three months ago, and three weeks after arrival the Government Authorities heard of her and established her in Melbourne to start what she believed was the first school of physical training in Australia. In another case she obtained an aided passage for a widow and child to go to New Zealand. On landing in Auckland the woman gave singing lessons, and within six months had married a very prosperous dairy farmer. A third example was that of a family which went to British Columbia and had done very well there.

COMMISSIONER DAVID C. LAMB (Salvation Army), said he proposed to criticise the paper frankly. In his judgment it was very disappointing because there was an entire lack in it of that spirit of adventure which was absolutely necessary at this stage of our history. The work of voluntary societies had been touched on, and he was under no illusions as to the importance of their work, but they were quite inadequate for dealing with the problem. If the Salvation Army and all the other bodies pulled their full strength, which, owing to lack of money they were unable to do, they would still be totally inadequate both for the needs of the overseas Dominions and the needs of this country. For seven long years this country had carried at least a million unemployed able-bodied men and women who were looking for work. The Chairman's suggestion for an interchange of Civil Servants was all right in its way, but the problem was one which had to be tackled by the people themselves.

When he was in Australia two or three years ago nothing impressed him more than the spirit of the people there. The people were to be trusted. If there was a little selfishness, it was amongst the newcomers, and he could quite understand it. A wife, for example, who had gone out recently and knew the struggle for existence in this country, did not want to see newcomers and possible competitors coming to Australia, but if one talked to her intelligently and gave her the assurances she needed she would respond. The heart of the people was sound, and when he asked them whether they would not like more people to come from this country and share in the sunlight and brightness of Australia they always responded.

The spirit of adventure was needed even in Government Departments, though it might be hopeless to look for it there. If he was asked "What are you going to do?" he would have to reply frankly that he did not know, and that was why he was disappointed with Lord Lovat's paper. Lord Haig was said to have died of heart strain due to the war. Knowing Lord Haig and his feelings for ex-Service men, personally he rather wondered whether he did not die from heart strain due to post-war conditions. Some time ago there was a discussion in this country as to whether Nelson had gone into battle without a plan or had worked on a plan carefully thought out beforehand. The verdict was given in favour of his having worked to a plan, because a letter was discovered from a captain of one of his ships who wrote to his wife just before entering the battle, "Why does not the governor stop signalling and let us get into the battle? We know what we have to do." He would like to ask, "Why does not the Government stop signalling and talking and get right into this problem?" The seriousness of the problem—the problem of the people at home and of the vacant spaces overseas—could not be over-estimated.

Lord Lovat was right in saying that the Government could not create the will to emigrate, but it need not trouble about that for the will was there. He would guarantee to fill every ship flying the British flag which was available with people who would be willing to go where work could be found. What was wanted was work, and he would say to the people overseas "Get busy and find work."

It was a great pity that an organisation like the Salvation Army, with its ramifications overseas, and its liability to be kicked if it made a mistake in any part of the world, was prevented by lack of money from pulling its full weight in the question of Empire settlement. Why did not the Government capitalise "the dole"? Two years ago he put up a proposal for overseas settlement for which General Booth was prepared to allot £10,000 and the Oversea Government Settlement Department were ready to contribute a corresponding amount. The scheme was to give rough training in ploughing and milking, and the Salvation Army undertook to train experimentally 500 workers and qualify them for settlement overseas. He thought

the Government would continue the payment of "the dole" to the wives and families of the men when they were in training, but he had had three letters from Government Departments to say that it could not be done, and that if the Salvation Army took a man and gave him that training, it must assume responsibility for his wife and children at the same time. That was an extraordinary position to take up, and involved a responsibility the Salvation Army could not assume.

Within the Empire everything was grown that the earth would produce, and everything dug up that the bowels of the earth contained; everything was made that the ingenuity of man could devise, and everything was available except the ability to organise resources so that there were no unemployed men and women. The present conditions were a danger, a scandal and a reproach not only to professional statesmen but to the commonsense of the British race. He read the other day that "adventure" was an ambiguous word, and that in things practical ambiguity might be perilous. Science, the pursuit of knowledge, was itself an experiment, but the experiment of the scientist was a carefully considered adventure designed for a constructive end.

THE REV. A. G. B. WEST (Vice-Chairman, Church of England Emigration Society), thought the problem of migration by far the most important before the Empire and this country to-day, and said he would welcome suggestions as to how to influence public opinion in the right direction both in this country and overseas. As Vice-Chairman of the Church of England Emigration Society, he realised that compared with the Salvation Army his Society had been slack, but he would ask Lord Lovat to give him a war cry for their 15,000 parishes so that something could be done with the Mothers' Unions and other bodies which were stopping the boys going.

It was very important for everyone to remember that the miner, and the man who had lived in a town, very frequently made a better farmer in a shorter time than a man who had first to unlearn all the farming he had learned in England.

Lord Lovat had spoken with approbation of what was being done in Newcastle, but he thought it would be a good thing if the disability now resting on municipalities were removed, so that some of the 60,000 children whom the municipalities now had to support could be sent to homes across the sea, where they would get used to the climate and conditions and be a less expense than they were here, while gaining a better outlook and living in better surroundings. Such a scheme would also remove the objection felt by certain authorities in Australia who did not wish their own standards of life to be altered by too great competition in labour.

THE HON. WILLIAM C. ANGWIN (Agent-General for Western Australia), said he had been interested to hear Commissioner Lamb say he could fill any number of steamers. That could certainly be done, but it was necessary to look at the facts as they appeared to those overseas. It would be an act of folly to send to Australia several shiploads of persons from this country without money unless there were a place for them to go to when they got to Australia. Australia was a large continent with a small population. It took time to develop the land, and unless the lands of Australia were developed it was impossible to find employment for large numbers of people. He represented a State—Western Australia—of nearly one million square miles of territory with a population of 388,000. With such a small population it was almost impossible to find the large amount of money required to open up the country. The development of that State had been extraordinary, but it took time. The State had still in the hands of the Crown 38 million acres of land, but the construction of railways was needed before people could settle on that land, and that would take

money. Taxation to do it all at once would be intolerable ; it had to be done by degrees. The Australian Government should exercise due caution and see that everyone who came to Australia was satisfactorily settled and able to enter employment immediately on arrival.

For six years he had been in charge of immigration in Australia and had seen some of the difficulties. It was better for a person to be out of employment amongst his friends in England than in Australia or any other Dominion. Australians wanted the British race to develop their country. He was sometimes asked whether settlement schemes could not be devised for people from other European countries, but Australia did not want that ; they wanted British people. If they threw their doors wide open they would have a larger population, but they wanted Australia to be peopled almost entirely by British stock.

The Chairman had referred to the Big Brotherhood Movement. That did not operate in every State of Australia, but boys who went to any part of Australia would be well looked after by some organisation or other ; the Government had made provision to see that all the boys were well looked after.

He differed from Lord Lovat and the Chairman in regard to nominations. The best nominations were those from relatives and friends ; they were far better than nominations from institutions. Unfortunately, some institutions did not give that care after arrival one would like them to do.

He had great confidence in Government employees, who in his experience had paid far greater attention to migrants in Australia than some people connected with certain institutions. Voluntary institutions did good work—some of them. Any man with a spirit of adventure who wasted his time in this country living on the dole was either mad or a fool. He was bound to be successful, if he was willing to work, in any part of Australia.

REAR-ADMIRAL E. A. TAYLOR, C.M.G., C.V.O., understood the most important thing was to get the young people to go out. £70,000,000 a year were spent on education in this country, and it was a scandal and disgrace that no part of the curriculum of that education had to do with the Empire. An enormous amount might be done to educate boys and girls if some instruction were given on the possibilities of the Empire and the glorious life that awaited people who went overseas. It could be done by the teachers, by books and above all by the cinema.

As regards domestic service, the teachers in the schools were inclined to look down on domestic service and encourage girls not to go in for it. That feeling must be broken down ; domestic service was just as fine a service as any.

MAJOR SIR HUMPHREY LEGGETT, R.E., D.S.O., proposed a very hearty vote of thanks, on behalf of the Council of the Royal Society of Arts, to the Chairman and to Lord Lovat for the admirable exposition they had given of what one of the speakers in the discussion had rightly called the greatest imperial problem existing to-day, and who had shown how the difficulties involved were being met.

It was unnecessary to recall the great services which both the Chairman and Lord Lovat had rendered in that connection. As Governor of South Australia, the Chairman had seen the problem on the other side of the water, and had turned his experience to good use in throwing himself wholeheartedly into the work at home. Lord Lovat, who was Under-Secretary of State for the Dominions, had shown that nothing escaped him. He had tramped the Empire from end to end ; he had fought overseas and he had played overseas ; and now he was devoting himself to encouraging others to go where he himself had already been.

Until ten years ago the British Empire played with the problem of migration. For 200 years they were supposed to have an Empire overseas, but the department in charge of it was sometimes rather curiously named. For 100 years it was called the Board of Trade and Plantations, and dealt chiefly with slaves. That was followed by placing the overseas Empire under the Secretary of State for War. The word "Dominion" was not known until recently. It was due more to the present Secretary of State for the Dominions and Colonies, Mr. Amery, than to any other one man in England to-day, that the problem was now being tackled in the way described in the paper, hampered, of course, by lack of money and by all kinds of practical difficulties.

If the question had been taken up seriously not ten years ago but twenty or thirty, something very effective might have been done. Only two years ago this country wasted £500,000,000 on the coal strike. Think what that would have done for the development of the Empire!

It was a great privilege for the Royal Society of Arts to have its room used for such an object, and on behalf of the Dominions and Colonies Committee of the Society, he wished to say that they would regard it as a privilege and duty to do whatever they could to assist this movement.

The vote of thanks was carried unanimously.

LORD LOVAT, in reply, said Commissioner Lamb had urged him to have a spirit of adventure. He was always ready for any adventure, and if Commissioner Lamb or anyone else would suggest any new method by which persons might be placed overseas or migration assisted in any way, he would be most ready to consider it, but he could not interfere with the work of other Government Departments and tell them how to conduct their affairs, nor could he venture with other people's money. Under the Act subsidies could be given up to 50 per cent. and, as the Chairman had said, there was not the least chance of getting Parliament to vote more than 50 per cent. towards a scheme it did not itself administer.

He had been asked how it was possible to stimulate the movement. He would suggest that the voluntary societies should make it clear that they had the Government behind them, and that for every pound they secured, if their scheme was approved, they would obtain a corresponding sum from the Government. Voluntary societies should also get hold of their corresponding society in the Dominions and assure them the best work they could do was to get a nominated passage, and that if they did that, the society on this side would select a suitable person to fill the vacancy.

Nominated passages were successful only if there was suitable selection on this side and someone on the other side who could look after the emigrant on arrival and place him in a suitable situation. For every successful settler there was an opportunity for someone else to obtain a nomination. He regarded the work as far more important than Government action, because risk was minimised and success made more sure.

A point had been raised about the 60,000 children on the rates who might be sent to Australia and elsewhere. That was a question of pounds, shillings and pence to a certain extent, and to an even larger extent a question of getting the consent of parents and relations, which would be difficult.

Admiral Taylor raised the question of what the schools were doing to notify the possibilities abroad or to give instruction about the Empire. Considerable action in that direction had lately been taken and a most valuable discussion held at the

Imperial Institute a short time ago. That was followed up by private meetings with representatives of the Teachers' Union and the Primary and Secondary School Associations. He felt strongly that the position should be put plainly in front of the children so that they might judge for themselves; no pressure, of course, should be put on anyone.

He was sure that everyone felt the question of the proper distribution of the white population of the Empire was the great question to-day, and would grow in importance as time went on. The various conferences held from time to time in Europe were already shewing signs of raising questions as to why the British Empire should keep certain parts of the world to itself and allow no one else in. It was up to the British race to put that right in a way that was satisfactory to the Dominions abroad and ourselves at home. We could not dictate policy outside this country, but the kindly relations which existed between this country and the Dominions permitted us to make suggestions to them which would be taken at their real value.

The proceedings then terminated.

NOTES ON BOOKS.

A SHORT CRITICAL HISTORY OF ARCHITECTURE. By H. Statham. London: B. T. Batsford, Ltd. 16s.

Statham's well-known book is a good introduction to the study of architecture. Readers will not agree with all the judgments passed by the author or by the editor who is responsible for the second edition, but no fault can be found with the way they challenge criticism. Statham says enough about the technique of building to enlighten a serious beginner who is not merely in want of an historical outline. He plunges *in medias res* by announcing that the bases of the science of building are the post and lintel system and the arcuated system; the principles of the former are self-evident while in chapter III we get an excellent account of the latter. The Romans erected domes over circular plans, a comparatively easy matter, while it was left to the Persian architects of Sassanian times to set a dome over a square compartment. The first known example of such work is the palace of Serbistan, which is presumed to date from the fourth century of our era.

The evolutionary processes in the technique and styles of building are enumerated by the author with clearness and illustrated by photographs and diagrams, and on the whole there is little inclination shown in the book to impress on history a neat conformity which it does not possess. Statham deplores the "deliberate adoption" of Gothic by the Germans, as the "rounded Romanesque might very well have been developed into a distinct German medieval style." He is forced to admit that Cologne cathedral enables us "to compare German with French Gothic under conditions advantageous to the former," and so can be acquitted of what had begun to seem like prejudice.

Notice in passing the attribution of Coleshill to Roger Pratt; Inigo Jones is usually supposed to have been the architect of this interesting mansion, which is certainly not unworthy of the greatest of English architects if it is by him, and an enormous credit to Pratt if Maxwell Aylwin is correct.

The editor's survey of modern architectural tendencies is careful but shrewd. Some people find it easier than others to detect the healthy influence of the *Ecole des Beaux Arts* in the less crude American sky-scrapers. "The twentieth century opened," says the editor, "with the architect ill-prepared to handle, with any real sense of understanding, the structural wonders of the age. The new movement is . . . an attempt . . . to re-establish that healthy partnership of heart and head which has produced the masterpieces of antiquity." And the masterpieces of any time.

It is a singular thought that whereas for a hundred thousand years the spirit of man was hampered for lack of scientific discoveries, at the present time it is confused and distracted precisely by the ingenuity which was formerly dormant. The temptation to do all that it has been found possible to do often proves irresistible. But even so, it appears we must take some of our modern wonders *cum grano salis*. An eminent British architect has prophesied that the life of an average New York sky-scraper is not likely to exceed forty years.

THE PICTURESQUE. By C. Hussey. London: G. P. Putnam's Sons, Ltd. 25s.

Mr. Hussey's book is learned, agreeable, full of interesting ideas, and unsullied by journalistic glibness. Without offering a new point of view, the author provides a new point of departure for a discussion of the way æsthetic theories have evolved in the last two or three hundred years. And if his readers are impelled to set aside the French nineteenth century painters for a moment, and to address their critical faculties to Claude and Poussin, he will have done them an unbargained-for kindness. A masterpiece is not seldom created under what the theorist may consider a misapprehension on the artist's part, and superficial romantic and scientific principles have led to the painting of fine pictures. There was evidently a bee of exceptional size in Claude's bonnet; but what exquisite honey the creature was able to distil! Mr. Hussey tells us all about the bee

"The picturesque," says Mr. Hussey, "can be seen to provide the first step in the movement towards abstract æsthetic values." This movement he traces with great skill. Titian first painted nature as he saw it, through his artistic vision, "not as he knew it to be from the testimony of his other senses." The man in the street came to admit that there was this "painter's view" of nature, which he called the "picturesque" view. Tintoretto and Poussin emphasised the aspects of nature that struck them as especially amenable to this picturesque view, while Claude added a certain element of freshness, based on close and affectionate observation, to his portrayals of landscape and seascape. "People began to enjoy actual landscapes that resembled his compositions." This is presumably what Oscar Wilde meant when he said that "nature imitates art." (Petrarch is often regarded as the first European in modern times to enjoy natural landscapes, but Mr. Hussey names Bishop Ulrich, of Augsburg, who lived in the tenth century, as "the first recorded admirer of the Falls of the Rhine at Schaffhausen.")

Having said so much the author proceeds to give a fascinating psychological analysis of eighteenth century appreciations of art. His knowledge is specialised, but he should have created a demand among more general readers than himself for a reprint of Uvedale Price on "The Picturesque." It was, indeed, a long time before the nineteenth century lost its love of too artificial design. The painter hero of Maupassant's *Fort comme la Mort* is discovered in chapter I looking for *un sujet poétique*. The truth is that possibly concrete objects were always thought of as

the essential apparatus of "composition." Recently "design" has been based on abstract forms, while nature has been left to adapt herself as best she can to this more sophisticated "painter's view." The best modern painters have the power of being able to introduce the atmosphere of nature into pictures built up of the most unrealistic touches. The beauties of nature and of artifice are made to strike the observer simultaneously, an effect which gives the greatest satisfaction to those precisely who insist on the distinction between the two, and who can, if necessary, wait for their experience of natural beauty till they next go to the country: I mean, who are more than content if a work of art confines itself to provoking in them a purely æsthetic emotion.

JÊN. By Mrs. Alfred Wingate. London: Crosby Lockwood.

Mrs. Alfred Wingate is deeply read in the lore and history of the Mongols. In her former work, "A Servant of the Mightiest," she described the amazing romance of Chingiz Khan, the son of a petty tribal chieftain, who became Khan of the Mongol nation in 1206, and conquered the whole of China and Central Asia. In "Jên" the scene is again laid in China of the thirteenth century, and the two principal characters are Kubilai, better known to most of us as Kubla Khan, and Marco Polo. The adventures of Marco, who, with his father and uncle, was the first European to travel in China, have become well known through the account of his journey which he himself dictated when detained as a prisoner in Genoa. They were so extraordinary that few of his contemporaries believed them, but later discoveries have justified him in almost every particular.

The Polos made their way by Mosul, Bagdad, Kashgar, Yarkand and across the great desert of Gobi to Shangtu, where they met Kubilai in 1275. They were received by him with the utmost kindness and retained in the public service. Marco became the most highly valued friend of Kubilai, and was employed on important missions in many parts of the empire. The account of these journeys is graphic, and Mrs. Wingate's description of the horrors of the desert of Cop is particularly fine.

The title will puzzle most English readers. What is "jên"? It appears to stand for the natural and moral law, the word of life, the "Logos" of St. John, and is the philosophy on which the faith and works of Kubilai were founded. The book, like its predecessor, is less of a novel than a prose epic or saga, and it gives a remarkable picture of the Far East in mediæval times.

THE ANCIENT MURAL PAINTINGS IN THE CHURCHES OF GLOUCESTERSHIRE. By Hobart Bird. Gloucester: Bellows.

Our prehistoric ancestors already adorned the walls of their caves with paintings, and the polychrome work of late palæolithic man has since its discovery been much admired for its unacademic and virile spontaneity. The mural paintings in the Gloucestershire churches have their place in a very long artistic tradition. They are all post-Norman, for, although a good deal of church decoration had been done in England as far back as the seventh century, no pre-Norman work appears to have survived various spasms of obliteration.

By the fifteenth century the mural paintings in English churches had become elaborate, none the less so on account of the narrow range of subjects that they dealt with. These usually were: (a) on the north wall St. Christopher carrying the child Jesus on his shoulder over a stream and holding a pole in one hand, with water and fish round his legs; (b) on the south wall St. Michael weighing souls,

holding a balance, often with a soul depicted in one scale, and a demon trying to pull down the other; (c) over the chancel arch, the Doom or Last Judgment."

The great Doom in Oddington Church, which is illustrated in Mr. Bird's book, was recently the subject of a special article in the Burlington Magazine. The paintings at Oddington date from the thirteenth century, and were discovered in 1913, having been whitewashed in the sixteenth or seventeenth centuries. The angels, devils and human souls are almost life size. I believe that the figure on the right which looks like the famous advertisement for Michelin tyres is, in fact, known locally as "Bibendum." What might be called the "devotional" value of such paintings must have been great in days before motor-cars and their tyres were invented.

Mr. Bird's book is most excellently arranged and printed. The introduction gives a concise summary of the history of mural painting, and the descriptions of the Gloucestershire churches leave nothing to be desired. The photograph of Kempley, taken in 1873, facing page 21, gives a good idea of the splendour of some of this medieval English art. It is unfortunate that all efforts to prevent these pictures from fading have proved unsuccessful.

P.B.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, MARCH 19. Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Special and Business Meetings.

Electrical Engineers, Institution of, Savoy Place, W.C. 7 p.m. Informal Meeting.

Geographical Society, at the Æolian Hall, 135, New Bond Street, W. 8.30 p.m. Mrs. Patrick Ness, "From the White Nile to Ruanda."

Victoria Institute, at the Central Hall, Westminster, S.W. 4.30 p.m. Dr. Erasmus Bushe, "The Precise Action of Faith on Thought Power, and the Mystery of its Influence on our Physical and Spiritual Welfare."

TUESDAY, MARCH 20. Civil Engineers, Institution of, Great George Street, S.W. 6 p.m. Mr. A. G. N. Chalmers, "Mining Methods Past and Present in the Morro Velho Mine of the St. John del Rey Mining Company and Lode-Changes which have necessitated an Alteration of System."

Metals, Institute of, at the Engineers' Club, Waterloo Street, Birmingham. 7 p.m. Mr. W. E. Ballard, "Non-Ferrous Tubes."

Photographic Society, 35, Russell Square, W.C. 7 p.m. Meeting of Scientific and Technical Group.

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Prof. J. S. Huxley, "The Behaviour of Animals." (Lecture V.)

Statistical Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 5.15 p.m.

Transport, Institute of, at the Institution of Electrical Engineers, Savoy Place, W.C. 5.45 p.m. Mr. J. L. Clewes, "Goods Transport by Road-Motor—its Financial and Statistical Aspects and Limitations."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Sir Bernard Pares, "Russian History from Peter the Great to 1861." (Lecture IX.)

At the Natural History Museum, South Kensington, S.W. 5.15 p.m. Mr. J. Ramsbottom, "The Evolution and Classification of Fungi." (Lecture III.)

Zoological Society, Regents Park, N.W. 5.30 p.m. Scientific Business Meeting.

WEDNESDAY, MARCH 21. British Academy, Burlington House, W. 5 p.m. Dr. M. Praz, "Machiavelli and the Elizabethans."

Geological Society, Burlington House, W. 5.30 p.m.

Meteorological Society, 49, Cromwell Road, S.W. 7.30 p.m. Mr. H. W. Newton, "The Sun's Cycle of Activity." (G. J. Symons Memorial Lecture.)

Microscopical Society, 20, Hanover Square, W. 7.30 p.m. (1) Professor D. C. Blair, "A Nerve Mechanism in the Capillaries of Muscle." (2) Dr. J. A. Murray, "Contribution to the Study of Diatom Markings." (3) Dr. G. S. Sansom, "A Portable Microscope Table."

THURSDAY, MARCH 22. Chemical Society, Burlington House, W. 4 p.m. Annual General Meeting. Prof. Dr. H. Brereton Baker, Presidential Address, "Constitution of Liquids—Some New Experiments."

China Society, at the School of Oriental Studies, Finsbury Circus, E.C. 5 p.m. Mrs. Florence Ayscough, D.Litt., "Memorial Temples and the Chinese Cult of Pattern-Men."

L.C.C. The Geffrye Museum, Kingsland Road, Shoreditch, E. 7.30 p.m. Mr. John Gloag, "The Development of Twentieth Century Furnishing."

Petroleum Technologists, Institution of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 5.30 p.m.

Royal Society, Burlington House, W. 4.30 p.m.

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Captain Martin Flack, "Physiological Aspects of Flying."

FRIDAY, MARCH 23. Chemical Industry, Society of, at Burlington House, W. 8 p.m. "The Mechanism of Fractionating Columns."

North-East Coast Institution of Engineers and Shipbuilders, at the Mining Institution, Newcastle-upon-Tyne. 7.15 p.m. Mr. H. G. Williams, "The Steering of Ships."

Physical Society, at the Imperial College of Science, South Kensington, S.W. 5 p.m. (1) Mr. W. D. Flower, "The Terminal Velocity of Drops." (2) Mr. Satyandra Ray, "Longitudinal Waves along a Rod." (3) Mr. J. J. Manley, "The Damping of Mercury Ripples." Demonstration by Mr. J. E. Calthrop of Die Raster-methode.

Electrical Development Association, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 7.30 p.m.

Royal Institution, 21, Albemarle Street, W. 9 p.m. Dr. Ernest Cohen, "A Physical Chemist in Search of Purity in an Impure World."

SATURDAY, MARCH 24. L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Dr. E. Marion Delf, "Light and Life."

Royal Institution, 21, Albemarle Street, W. 3 p.m. Sir Ernest Rutherford, "The Transformation of Matter." (Lecture III.)

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VOL. LXXVI.

FRIDAY, MARCH 23rd, 1928.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.(2.)

NOTICES.

COUNCIL.

A meeting of the Council was held on Monday, March 12th. Present: Sir Philip Magnus, Bt., in the Chair; Sir Charles H. Armstrong; Lord Askwith, K.C.B., K.C., D.C.L.; Mr. Llewelyn B. Atkinson, M.I.E.E.; Lord Bledisloe, P.C., K.B.E.; Captain Sir Arthur Clarke, K.B.E.; Mr. Peter MacIntyre Evans, M.A., LL.D.; Sir Alexander Gibb, G.B.E., C.B.; Col. Sir Arthur Holbrook, K.B.E., M.P.; Major Sir Humphrey Leggett, R.E., D.S.O.; Sir Richard Redmayne, K.C.B.; Col. The Master of Sempill; Sir George Sutton, Bt.; Mr. Alan A. Campbell Swinton, F.R.S.; Mr. Carmichael Thomas, and Lt.-Col. Sir A. T. Wilson, K.C.I.E., C.S.I., C.M.G., D.S.O., with Mr. G. K. Menzies, M.A. (Secretary) and Mr. W. Perry, B.A. (Assistant-Secretary).

A vote of condolence was passed with Sir Frank Warner on the death of Lady Warner.

It was reported that the number of entries for the March Examinations was approximately 28,400.

Further consideration was given to the question of the award of the Society's Albert Medal for 1928.

It was reported that an Appeal for £2,000 in order to purchase, repair and preserve permanently the beautiful cottages known as Arlington Row, Bibury, had been issued. (Fellows interested in this matter are requested to apply to the Secretary for Copies of the Appeal).

The Secretary was authorised to issue notices of the offer of the Swiney Prize for the best published work on Medical Jurisprudence. (See page 454).

Papers suggested for reading before the Society were considered.

Sir Arnold Wilson and the Secretary were nominated to represent the Society on a Committee appointed by the Council for the Preservation of Rural England to consider the question of Petrol Stations.

The following candidates were duly elected Fellows of the Society :—

Blair, Alexander Campbell, Bakewell, Derbyshire.
 Bune, J. Godfrey, Hampton Wick, Middlesex.
 Clilverd, Graham B., London.
 Cruickshank, William Donald McDonald, Lahore, Punjab, India.
 Curmi, Captain Vincent Alfred, Esquimalt, B.C., Canada.
 D'Rozario, Antoney Constantine, Chepauk, Madras, India.
 Eeles, F. H., London.
 Gallagher, W. J., London.
 Green, Robert Leonard, Kew, Surrey.
 Hadfield, Thomas L., Sheffield.
 Haworth, Wilfrid George, Keswick, Cumberland.
 Hughes, Charles Garland, London.
 Judd, Walter, London.
 Macnab, Iain, London.
 Marteau, Fernand A., London.
 Naylor, Arthur Holden, M.Sc., Penang, Straits Settlements.
 Ogden, James Roberts, J.P., Harrogate.
 Pesaro, Gr. Uff Lino, Milan, Italy.
 Sivyer, Leonard D., Los Angeles, California, U.S.A.
 Speedy, Captain Patrick Francis Borrowdale, Baltasound, Unst, Shetland.
 Stevenson, James Arthur Radford, Ottery St. Mary, Devon.
 Trewby, Miss Olive, London.
 Wright, Charles Herbert, London.

Other formal and financial business was transacted.

SIXTEENTH ORDINARY MEETING.

WEDNESDAY, MARCH 14th, 1928. WILLIAM MCCLELLAND, ESQ., C.B., O.B.E., M.I.E.E., Director of the Electrical Engineering Department, Admiralty, in the Chair.

A paper entitled "The Lead Acid Cell : its Place in Modern Industry" was read by Mr. Harold G. Brown, A.M.I.E.E., of the D.P. Battery Company, Ltd. The paper and discussion will be published in the *Journal* dated May 25th.

SWINEY PRIZE.

The Council have to give notice that the next award of the Swiney prize will be in January, 1929, the eighty-fifth anniversary of the testator's death. Dr. Swiney died in 1844, and in his will he left the sum of £5,000 Consols to the Royal Society of Arts, for the purpose of presenting a prize, on every fifth anniversary of his death, to the author of the best published work on Jurisprudence. The prize is a cup, value £100, and money to the same amount.

The award is made jointly by the Royal Society of Arts and the Royal College of Physicians. In accordance with the arrangement with the Royal

College of Physicians, the award next year will be for a work on Medical Jurisprudence.

Any person desiring to submit a work in competition, or to recommend any work for the consideration of the judges, should do so by letter, addressed to the Secretary of the Society, not later than November 30th, 1928.

The following is the list of the recipients :

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|---|--|
| 1849. J. A. Paris, M.D., and J. Fonblanque, for their work, " Medical Jurisprudence." | work, " A Systematic View of the Science of Jurisprudence." |
| 1854. Leone Levi, for his work, " The Commercial Law of the World." | 1889. Dr. Charles Meymott Tidy, F.C.S., for his work, " Legal Medicine." |
| 1859. Dr. Alfred Swayne Taylor, F.R.S., for his work, " Medical Jurisprudence." | 1894. Thomas Erskine Holland, D.C.L., for his work, " The Elements of Jurisprudence." |
| 1864. Henry Sumner Maine (afterwards K.C.B.), D.C.L., Member of the Legislative Council of India, for his work, " Ancient Law." | 1899. Dr. J Dixon Mann, F.R.C.P., for his work, " Forensic Medicine and Toxicology." |
| 1869. William Augustus Guy, M.D., for his " Principles of Forensic Medicine." | 1904. Sir Frederick Pollock, Bart., and Professor F. W. Maitland, for their work, " The History of English Law before Edward the First." |
| 1874. The Right Hon. Sir Robert Joseph Phillimore, D.C.L., for his " Commentaries on International Law." | 1909 Dr Charles Mercier, for his work, " Criminal Responsibility." |
| 1879. Dr. Norman Chevers, for his " Manual of Medical Jurisprudence of India." | 1914. John W. Salmond, K.C., for his work, " Jurisprudence." |
| 1884. Sheldon Amos, M.A., for his | 1919. Dr. Charles Mercier, for his work, " Crime and Criminals." |
| | 1924. Professor Sir Paul Vinogradoff, F.B.A., for his work, " Outlines of Historical Jurisprudence." |

PROCEEDINGS OF THE SOCIETY.

TENTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 1ST, 1928.

SIR DAVID PRAIN, C.M.G., C.I.E., M.B., LL.D., F.R.S., in the Chair.

The following paper was read :—

MODERN ASPECTS OF RUBBER CULTIVATION.

By CHARLES HERBERT WRIGHT, B.A.

INTRODUCTION.

After devoting the last five years to the study of the Science of Rubber and the many branches of Botany, it occurred to me that the observations made

in that connection might be of some value to those interested in the plantation side of the industry.

For this purpose a few remarks will be made relative to some of the more important aspects of to-day, embraced by soil conservation, tapping systems, manuring, and improved strains, supplemented with slides which have been taken in Ceylon, Malaya, Java and Sumatra during 1926 and 1927.

It will be convenient to begin with a discussion of the soil.

THE SOIL FACTORS.

Soil Science.

By this term is understood the application of science as regards soil conservation, the cultivation of cover crops and drainage.

Soil Conservation.

In the past little or no attention was paid to safeguarding the capital on which the growth and yield of rubber is in the main dependent. The cost of such neglect is evidenced to-day in the exposed roots, accompanied by weakly affiliated canopies, to be seen on many estates, the evils of erosion being more acutely felt in hilly and undulating land than in the flatter areas.

Once the burn has been completed—the majority of estates being opened from land formerly occupied by jungle—heavy losses of top soil are experienced, where no steps are taken to combat the adverse influences engendered by erosion. It is this top soil, and more especially the finely divided particles that are so readily washed away in a tropical downpour, which, in a large measure, determines the future aspect of the rubber. To retain these soil particles, it is very necessary that a cover be established at once; a leguminous cover is to be preferred, though the growth of grasses and other flora is more desirable than the complete absence of cover.

Once the importance of this factor has been realised a great step has been taken towards securing a property yielding 500 as against one yielding 300 lb. and less, per acre.

Further considerations are prompted by the lie of the land. In the case of table lands, as in many Malayan and other soils, little additional provision is needed; where, on the other hand, distinct slopes of a steep or undulating nature are concerned, it is not sufficient to rest content with a policy of ground covers only.

In such cases contour terraces and contour buttresses play a very important role.

Contour Terraces.

These present features of considerable variation, and have been productive of several distinct types.

As a general rule, a series of contours are taken at fifteen to twenty feet apart, according to the lie of the land, terraces or platforms being cut back at a slight gradient into the face of the hill along the line of contours.

A favourable depth for such platforms may be taken as six feet, which allows a satisfactory purchase for the rooting systems of the rubber in the later stages of its development ; this depth can be increased with advantage ; it is not always economical to countenance smaller dimensions, a platform only three feet deep being undesirable.

In many cases the terraces or contour platforms are found to be continuous, while in others they consist of a series of platforms cut into the hill, six feet deep by eight feet broad, connected with a tapping path three feet wide ; the latter type is most economical and can be commended. As regards the surface of the platform, this may be left intact or perforated with a series of blind drains.

The advantages of such a system are manifold. Not only is surface erosion reduced to a minimum, the silt being washed to the back of the terrace, but the rainfall is trapped on a sloping shelf, a ready percolation and more regular distribution of soil water being thereby secured.

A modification, or rather a simplification, of such a system is to be found in a series of isolated contour platforms which are not connected with one another by means of tapping paths ; such a type is suitable for gently undulating land, but does not appear to advantage on steep ground where a continuous terrace is necessary to facilitate the progress of the tappers, enabling them to move more quickly from tree to tree.

It has sometimes been supposed that—and even to-day this belief still finds its adherents—by cutting back into the face of a hillside, thereby exposing a wall of subsoil to the rooting systems of the rubber, an insurmountable barrier is set up, arresting the subsequent development of the roots and interfering with the growth rate generally. In actual fact, however, the roots do not penetrate this subsoil wall, but turn vertically upwards, and are to be found a few inches below the surface.

This observation leads us to certain principles to be observed in planting on terraces.

In the first place, it would be prejudicial to the ultimate value of the tree to plant it in close proximity to the back of the terrace ; in such cases little lateral purchase would be afforded one side of the tree, thus incurring the liability of lean and subsequent uprooting in heavy winds. In the second place, it would involve a departure from sound cultivation to allow too steep a wall at the back of the terrace, exaggerating the vertical tendency of the lateral roots, and indirectly affecting the purchase of the organs involved. A distance of three to four feet from the front of the terrace may be considered convenient when determining the position of the tree.

Contour Buttresses.

If this system is taken in hand at an early date, it is a matter of difficulty to assign the balance of favour one way or the other, when a comparison is drawn between the contour buttress and the contour terrace.

In the system of contour buttresses the rubber is planted on the contours before determining the aspect of the future planting.

Subsequent to the planting of the clearing the soil is *changkolled* back from behind the rubber, resulting in the creation of a platform bounded by a bund, or buttress, consisting of the material which has been drawn back and heaped on the outer margin. Additions are made to these platforms annually, more earth being taken from behind the rubber to increase the width of the terrace and the height of the marginal buttress, with the result that a series of platforms has been completed by the time the rubber comes into bearing.

It is sometimes objected that this continual scraping involves unnecessary injury to the roots ; but rubber brought into bearing by observing such a system compares very favourably with the growth rate and appearance obtaining in the average terraced plantation.

As regards the cover which is necessary for holding up the soil on the embankments, where these systems are in vogue, the growth of a leguminous crop is preferable to an admixture of grasses.

The root systems are not confined to the shelves of the terrace, but are to be found ramifying in the surface layers of the embankment above and below the actual platform and making use of the available plant foods in these areas, the availability and supply of nutrient material being more favourably affected by the presence of a leguminous cover crop.

Stone Terraces, etc.

In Ceylon, in particular, stone terraces or walls are to be found stretching across the face of a hill ; in some cases individual terraces are found at the base of a tree ; both types are intended to hold up and collect the surface soil washed down the hill face.

To a degree they may be said to serve their purpose, but their utility is in no way to be compared with the platform system, whereby not only is surface soil trapped by the terraces but the removal of the soil from the neighbourhood of the roots is prevented.

In Java it is not unusual to observe the execution of similar principles ; but in such cases the stone is often replaced by a thick growth of pruned *lamtoro*, a leguminous tree which enjoys a certain measure of popularity in the cultivation of coffee.

It is convenient now to pass on from this point to consider the efficacy of leguminous covers.

THE ROLE OF COVER CROPS IN ESTATE PRACTICE.

The Significance of Leguminous Cover Crops.

Before enumerating the immeasurable benefits to be conferred on the development of rubber by the introduction of such an essential mode of cultivation, it would not be remiss to review in brief the disastrous effects occasioned by the absence of cover.

At one time a certain school of thought advocated a system of clean weeding for rubber, in spite of the fact that Heveas, in their native habitat in the Amazon valley, flourish under forest conditions in an assemblage of miscellaneous jungle vegetation. Unfortunately, this creed still has a large following, influencing its disciples to such an extent as to overlook the steady decline in crop returns, for which such a system is responsible.

The supposition that the rooting systems of rubber should alone be in possession of the soil, foreign growth serving to deprive the trees of a certain quantity of nutrient material, has no doubt been responsible for the evolution of such a doctrine. At this point it would not be out of place to point out that some of the best grown rubber, with remarkably thick succulent bark and vigorous canopies, is to be found in abandoned areas entombed in a forest of tall jungle trees and a heavy growth of *blukah*.

By leaving the rubber in sole possession of the soil, it is not long before the roots are in undisputed possession of, not the top soil, but the subsoil, the humus and soil particles of import being accumulated in the valleys; in non-undulating areas the evils of root erosion are not as pronounced.

A not uncommon picture, which meets the eye on sloping ground, where a system of clean weeding has given carte blanche to the incursions of erosion, is a mass of exposed rib-like lateral roots, the roots in many cases suffering from sun-scorch, and an attack of *Diplodia*, the bark being "hide-bound," hard and gritty, and the canopies sparsely affoliated.

It is inconceivable that any cultivation could thrive under such conditions. The surface soil in many cases becomes hard and baked, acting to a marked degree as a waterproof layer, thus impeding the access of rainwater to the imprisoned rootlets below, the effects being accentuated in the case of heavy clays which, on the one hand, dry out very readily to a cement-like consistency and, in the other, present a stiff, compact, putty-like mass in the wet seasons. There are no buffer effects to counteract the loss of water from the soil by evaporation, and evaporation of water from the bark, with the result that a hard, gritty cortex is developed, and the duration of the latex flow adversely affected. The microfauna and microflora of the soil, which make up the invisible garden of the subsurface, cannot be expected to function with the same degree of efficiency under such adverse conditions of excessive heat radiation and loss of soil water by evaporation, as in soils where such unnatural conditions do not obtain.

A more inimicable complex of features than those presented above is difficult to imagine.

We will now deal with the beneficial influences exercised on the growth of rubber by observing a system of cover crops from the outset, dealing with the mechanical, the chemical and physical aspects of the question.

Mechanical Considerations.

The mechanical considerations are concerned with the prevention of wash, and the opening up of the soil by the root systems of the cover facilitating the passage of rainwater along the channels of an induced honeycomb structure ; these two all-important factors cannot operate where a system of clean weeding is practised.

Chemical Considerations.

The chemical, as distinct from the mechanical, aspects may be said to pass imperceptibly into the physical, and can be conveniently discussed at greater length. As the result of the presence of a leguminous crop on any soil, certain very definite chemical benefits are shown to accrue. It must not be supposed that such a crop merely serves the function of an inanimate cushion, with the sole purpose of trapping silt ; on the contrary, the lower layers are composed of rotting foliage, varying from three to nine inches in depth, which are continuously being returned to the soil, enriching it both chemically and physically.

It is interesting to examine a handful of weathered, barren *laterite* exposed to the effects of the sun and weather, and compare it with a similar sample from a similar area under a leguminous cover. In the latter case a barren *laterite* soil has darkened considerably and reverted as the result of the incorporation of worm castings with the rotting material to jungle soil conditions. The value of the earthworm is not always appreciated ; it has been calculated that earth worms bring up to the surface ten tons of soil per acre per annum.

Although the effect of the incorporation of this never-ending supply of humus is strictly physical, it is also to be viewed from the chemical standpoint. In brief, the incorporation of humus leads to the granulation of hard, compact clays, breaking them down into friable loams, which, in addition to being chemically richer, are rendered more amenable to æration and the passage of soil water ; sandy soils, on the other hand, as the result of the addition of colloidal matter, are both chemically enriched and physically improved, the soils receiving more " body " than previously.

Finally, the shedding of the nitrogenous nodules to be found on the roots of the leguminosæ involves the addition of considerable quantities of nitrogen to the soil.

It has been found, at Rothamsted, that the growth of a crop of clover in one year added no less than three cwt. of nitrogen per acre to the soil, consequent

on the activity of the nodular organism, the additional protein being broken down into nitrate.

When the significance of such a quantity of nitrogen *gratis* is realised, nitrogen being perhaps the most important element in the construction of plant tissue to be derived from the soil, the value of a leguminous cover crop might well be considered from a different standpoint.

The Physical Effects.

The main physical effects centre round the water relations of the soil and the atmosphere; the interposition of a cover between the soil and the sun serves to reduce the ill effects of heat radiation which obtains on bare soils, by contributing to the maintenance of a humid atmosphere in the region of the tapping panels. It is significant in this connection to note that on many estates where the soil is exposed and unduly heated, the bark on examination under the microscope is seen to contain a greater number of stone cells than in the case of estates under cover; such cells interrupt and break up the laticiferous cylinders, thereby decreasing the yield of latex.

The Effect of Covers.

It is of interest to comment on the changes which have been effected by the introduction of cover plants—more especially leguminosæ—on areas previously clean weeded and exposed to the sun.

Perhaps the most striking is the recovery of the canopy; in one case, in particular, it was incredible that the dense massive crowns of foliage in an area under a mixture of *Centrosema pubescens* and *Vigna* could have at one time been in the plight of their skeleton-like neighbours, which had never enjoyed the benefits of cover. This remarkable crown recovery is often out of all proportion to the girth of the trees; the customary ratio between leaf development and girth is disturbed to a degree of absurdity, the girth of the tree being miserably out of proportion to the development of the crown.

Other changes are to be observed in the thickness and succulent nature of the renewed bark, as opposed to the hard, thin bark on clean-weeded areas. There is evidence to show that the maintenance of a humid atmosphere in the region of the cut prolongs the flow of latex, in some cases accelerating it, trees still continuing to drip when the flow on contiguous and uncovered areas has ceased.

Finally, it might be claimed that the increased production of latex from areas under cover, but previously clean-weeded, is, to some extent, due to the honey-combing effect of the soil, induced by the ramification of the roots of the cover crop, producing a sponge-like mechanism for retaining the rainwater.

The Covers Employed for Rubber.

With a few exceptions, the presence of grasses and ferns, provided these are

regularly slashed at monthly intervals is to be preferred to the complete absence of cover of any description.

Some very valuable stands of rubber are to be found where a system of slashed grasses is encouraged, and some very backward stands where a system of clean-weeding is in evidence. The wiry type of grasses, with a condensed habit of growth, presenting a compact, interwoven carpet, three to twelve inches high, should be avoided; similarly, the tall, broad-bladed type, with thick rhizomes, or creeping underground stems, such as *lallang*, is not to be countenanced.

Ferns with heavy, bulbous root growth are not advisable, the growth of grasses and ferns answering to this description definitely retarding the growth of the rubber.

It is not suggested that a grass or fern vegetation may be favourably compared with leguminous cover. This last type of cover is to be divided into three classes, the herbaceous, the shrubby, and the tree type, the last-named being strictly outside the pale of such nomenclature.

The shrubby type includes such genera as *Crotalaria*, *Tephrosia*, *Cassia*, *Balaría* and *Clitoria*; species of the two first named are in common use, their function being not so much to prevent wash as to enrich the soil, the growth being periodically lopped and the prunings mulched into the soil. These plants produce a dense lupin-like growth, the *Tephrosias* in particular often attaining a height of five to six feet.

The quantity of green manure obtained from the loppings of these plants is considerable, but as far as erosion is concerned, the rainwater has little difficulty in cutting channels through the gaps obtaining between the forest of woody stems, in spite of the carpet of fallen leaves.

The tree type is represented by *Albizia*, *Dadaps* and *Lamtoro*. In Ceylon, in particular, the custom still holds good in certain cases of planting a row of *Albizia* trees between two rows of rubber, cutting them out after six years, when the rubber comes into bearing. In certain cases scattered *Albizia* trees remaining from previous tea cultivation are to be found in old rubber; it is surprising to observe the remarkable influence of such leguminous trees on the growth of the rubber.

A system whereby a dozen such trees per acre at sixty by sixty feet apart were left in the rubber might well be exploited to advantage; it is significant to note that in the Dutch East Indies the practice of resuscitating washed-out soils by the interplanting of *Albizia* trees with the rubber is viewed with favour. *Lamtoro* (*Leucana*) can be employed for the same purpose.

The herbaceous type includes *Calapogonium*, *Centrosema*, *Pueraria*, *Vigna* and *Mimosa*; the last-named is a creeping thorny bramble type, being strictly neither shrubby nor yet herbaceous. The characteristics of these different plants can be profitably discussed.

Calapogonium mucunoides produces a dense cover varying in depth from eight inches to a foot and a half or more, possesses a broad leaf approximately

two inches in length, and is a very heavy seeder. Unfortunately, it dies back once every twelve to eighteen months; it is at this stage that the incursion of grasses is to be most feared, the area originally under Calapogonium reverting to grasses if not kept free of weed during the germination of the Calapogonium seed and the growth of the young plants.

Pueraria javanica generally produces a denser and thicker cover than Calapogonium; the leaf is larger and broader at the base; it is to be preferred to the former plant, as enjoying a greater degree of permanence, rarely dying back to the same extent as Calapogonium.

Vigna oligosperma, more correctly known as *Dolichos Hoseii*, is a small-leaved legume which rarely attains a depth of more than one foot. It has a very remarkable characteristic in that it produces only a small quantity of seed. It cannot be said to suppress the growth of weeds to the same extent as Calapogonium and *Pueraria*; at the same time, it is a more permanent cover, rarely dying back before the lapse of a period of four years.

Centrosema plumierii and *pubescens*: the former species has a broader leaf and is characterised by a large white bean-like flower with a purple centre, as opposed to a narrower and more pointed leaf, in conjunction with a smaller heliotrope flower, in the case of *pubescens*. The growth habits of *C. pubescens* are more favourable than those of *C. plumierii*; the growth is more condensed, affording little or no facility for the incursion of weed and grasses; the quantity of leaf returned to the soil is in many cases considerably greater.

Mimosa invisa might well be described as the super-cover; it has, however, several serious drawbacks. This rambling, thorny cover, akin to bramble trailers supporting many compound and finely-divided leaves, may attain a depth of two to three feet, the quantity of humus returned to the soil being very great. It is reputed to confer a degree of perfection on the texture of soils, opening up cold clays, adding body to sandy formations, to an extent unrivalled by other covers. It is a great misfortune that its thorny nature, its tendency to let in lallang, and highly inflammable properties should set up such a formidable barrier as to limit the practicability of its use.

Of the above-mentioned which can be employed with such marked success, only *Centrosema pubescens* and *Vigna oligosperma* have shewn themselves to be tolerant of the average shade conditions to be found in mature rubber.

The Growth Rate of Covers.

It must be realised that it is not sufficient to allow covers to take care of themselves. The influence of many factors must be appreciated, and considerable pains taken, before the cumulative benefits of a cover crop policy can materialise. A few observations in this connection are worthy of consideration.

The Physical Texture of the Soil.

As a general rule it is not a simple matter to establish a cover crop on a hard

compact clay, which has been exposed to the influence of sun and weather for a term of years without previous special treatment.

It is possible to observe covers growing in contiguous areas where the growth of one block is more than double that of another, the superior growth being due to the loose, open texture of the more favoured soil.

It is possible to walk through a field of rubber under cover and where the cover is very dense, suddenly fall into a pit occasioned by the removal of a diseased tree. Such experiences impress on one's mind the value of aeration and loose texture on the growth of covers.

The Soil Water.

Of equal importance is the distribution of soil water ; on the sides of drains, in cup-like valleys where the distribution of soil water is most marked, the growth of the cover is in most cases superior to that on other parts of an estate.

The most striking example of the influence of soil water was afforded by the growth of *Calapogonium* in a particularly well-watered area ; the growth was so vigorous that it not only climbed the blades of lallang in the area in question, but killed it out as evidenced by the dead fibrous rhizomes, which were revealed when the soil was opened with a changkol.

Where the natural factors are unfavourable, as regards the texture and distribution of soil water, it is most essential to prepare the ground by previous envelope forking or light changkolling, the cover being broadcast in the loosened strips. At the same time the young cover should be kept free of weed, the growth of which will otherwise tend to smother the seedlings in their initial stages of development.

Where such practice is observed the successful establishment of cover should not present great difficulty.

It is sometimes customary to run a native plough through the area to be planted with covers ; the results of such practice are very satisfactory. Month by month the soil requires to be broken up either side of the spreading strips ; otherwise the cover tends to " bush " and come to a standstill.

Failure to grasp the significance of soil texture and aeration leads in the majority of cases to disastrous results, the cover in question being unwarrantably condemned through neglecting the significance of the law of limiting factors.

The Exhausted Soil Factor.

On parts of many estates to-day it is almost impossible to establish covers, owing to the poverty of what little original top soil remains as the result of clean weeding. In such cases small pits can be dug and the top soil scraped in, the cover being planted and manured with cow-dung or artificials ; occasionally baskets of good soil are put out in the field to encourage the growth of the legume in such areas. It is interesting to note that the effect of Phosphoric acid on the development of the colonies of the Nitrogen fixing organism

Pseudomonas radicola, which invades the roots, giving rise to the nodular development to be found in the leguminose, has far-reaching quantitative results. It has for a long time been known that pasture manured with Basic Slag, containing 20 to 30% Phosphoric acid, rapidly reverts to clover (a leguminous plant) the development of which is not to be found to the same extent in fields where a dressing of Phosphoric acid has been omitted. The growth of the colonies is enhanced by the Phosphoric acid to such an extent that the number of natural inoculations increases rapidly, indirectly increasing the growth rate of the legume. As far as tropical experience is concerned, it was observed in the case of *Calapogonium* treated with Phosphates that the growth of the manured areas had trebled the growth of the unmanured controls. Unfortunately, too little credence is placed in the practical results to be obtained by dressings of Nitrogen and Phosphoric acid for leguminous covers. In many cases the results have been vitiated by failure to open up the soil beforehand, and by supplying the dressing in one instead of several doses, the greater part being absorbed by the rubber.

A dressing of 60 lb. Superphosphate and 40 lb. Ammonia sulphate per acre, the quantities to be increased and the proportions altered according to circumstances, is not without its advantages, the quantity of humus to be returned to the soil being considerably increased and the suppression of weeds being more pronounced.

Finally, it is possible, with care, to establish *Mimosa* in old rubber where the shade is not too dense, the weak, straggling development being subsequently suppressed by the introduction of *Centrosema pubescens*, the *Mimosa* obtaining a footing in soils which at first sight would strike despair into the hearts of the most determined.

Debatable Features.

It is sometimes contended that the growth of a leguminous cover, as the result of loss of water by evaporation from the total leaf spread, takes more water out of the soil than is desirable, exercising a prejudicial influence on the growth of the rubber. In the case of *Centrosema pubescens* this contention may contain a certain germ of truth, but it is doubtful whether such a state of affairs can be considered to have any significance for the other cover crops mentioned. It should be pointed out that this aspect has not yet been definitely determined; should the validity of such a belief be established the disadvantages incurred in this respect can be obviated by periodical slashing of this cover at quarterly or less frequent intervals. Such an operation is to be commended, whether or no the water loss factor be significant.

Of much greater importance, however, is the question of staling; this term embodies an expression of soil sickness, the accumulation of plant residues and excretory products rendering the soil unsuitable for the further growth

of the plant in question ; this phenomenon is not uncommon, and is well illustrated by the staling effects to be found in fungal cultures.

It has been observed in practice that after a period of four or more years an apparently healthy cover has for no apparent reason died back and disappeared ; such behaviour has been associated with staling or soil sickness, which can be combatted by turning the cover into the soil, thereby improving the soil conditions, or by a rotation of cover.

The advantages of this last practice are for the future to decide. It is sufficient to remark that it is contrary to all ethics of agriculture to allow a herbaceous crop to remain in permanent possession of the soil, with the possible exception of pasture. Where possible the cover should be turned in every eighteen months over the whole estate or at more frequent intervals ; where financial and other considerations do not permit of such practice, at least a quarter to a third of the area should be treated annually once the whole estate has been put under cover.

It is not altogether desirable to changkol the covers into the soil, the accompanying root disturbance being associated with a set-back to the canopies. The cover can, however, be heaped and envelope forked into the soil, attaining the same end without courting the appearance of undesirable phenomena.

The incorporation of the cover, in the green or dry state, is probably more correctly to be regarded as conferring physical rather than chemical benefits on the soil.

Selection of Covers.

Under conditions of heavy shade little choice is afforded. At present *Vigna* and *Centrosema pubescens* have alone shown themselves capable of growth in mature rubber, where the density of the canopies is appreciable.

Other covers are to be found, which more correctly belong to the shade intolerant class, such as *Calapogonium* and *Centrosema plumierii* in mature rubber ; but in such cases the degree of direct illumination is generally pronounced and local.

In most cases, with the exceptions enumerated, the leguminous covers at present in use die back when the open nature of a new clearing has been replaced by the shade conditions of mature rubber.

Where new clearings are concerned a mixture of *Pueraria* and *Calapogonium*, *Centrosema* and *Calapogonium* produces satisfactory results, the *Pueraria* and *Centrosema* ultimately tending to replace the *Calapogonium*, when this cover dies back at the end of a year to eighteen months. In the shade the balance of favour probably rests with *Centrosema pubescens* rather than *Vigna*, or an admixture of both.

The advantages of mixed covers over the exclusive use of one type only are being gradually realised.

DRAINAGE AND ITS ASPECTS.

What is the purpose of drainage ?

Are we correct in ascribing a single function to this aspect of cultivation ? Or are we to regard it as a definite complex ? Perhaps this term has come to be associated by many with the removal of surplus water from a waterlogged soil ; such a conception would, however, indicate an incomplete grasp of the significance of this important operation.

Drainage may be regarded as a barrier to break up the impetus of tropical rains on hilly land, counteracting the disastrous effects of cumulative wash, as a means whereby a gradual percolation of water in the superficial layers is ensured, as an outlet for securing the lowering of the water table, and as a soak away for preventing the accumulation of water in its passage from higher to lower levels.

The Distribution Factor.

When a mass of water, with the impetus and volume associated with a tropical downpour, suddenly falls on a hilly area or an undulating stretch of land, it quickly mounts to a head which, if unbroken, increases with the gradient of the slope, removing considerable quantities of top soil in its train.

The force of such a miniature cascade can be broken by a series of drains across the face of the slope, thus preventing the formation of a continuous sheet of water which would otherwise stream off the surface. In Ceylon a system of herring-bone drains consisting of a number of lateral drains opening into main leaders enjoys considerable popularity ; the object of such a system is to remove the water as quickly as possible, the laterals emptying into the leaders.

In Malaya and Sumatra a different system with altogether different principles obtains, which is known under a variety of names, such as blind drains, silt pits, etc. In these countries instead of aiming at running the water off the surface, the water is trapped and held in a blind drain from which it ultimately percolates through the soil.

These drains vary in length, and are generally laid out on the contours ; the average drain is 10 ft. long, $1\frac{1}{2}$ ft. wide, 1-2 ft. deep, the earth being thrown up as a bund in front of the drain.

The last-named practice is to be preferred to the herring-bone system, inasmuch as it retains the water on the surface and allows it to percolate gradually among the rooting systems of the rubber, in addition to breaking the backbone of cumulative wash.

The Percolation Factor.

To secure the ready passage of water through the surface soil the system of silt pits, already mentioned, can be employed for both flat and rising ground.

The form and arrangement is very variable. The simplest type consists of a series of blind drains end to end, separated one from the other by a " stop "

or plug of earth, three feet long, at varying intervals of twenty to thirty feet apart, with or without a protective bund or embankment in front or behind the pit.

Other types are to be found in the half-moon system, where two pits, in the form of a horse-shoe, are dug directly behind the tree, or in the "fire box" silt pit, where a deep square pit four feet deep is dug, forming a figure five or quincunx with a group of four trees.

At first sight such systems might appear to be superfluous, but this is not the case. In many instances an increase of fifty pounds or more of rubber per acre has been attributed to such a system. If the rainwater is unable to percolate freely among the roots of the rubber the greater part runs off the surface, instead of being absorbed by the invisible root hairs on the white wiry rootlets. Any appreciable reduction in the quantity of water taken up by the tree, apart from being reflected in an inferior growth, can be correlated with a corresponding decrease in the flow of latex and *vice versa*; it is not unnatural that by cutting off the water supply of the tree the flow of latex should be adversely affected. On one and the same soil it is possible to find vigorous patches of rubber in slight hollows, surrounded by weakly affoliated and stag-headed trees, the vigorous patches deriving the benefit of the surface water accumulated and temporarily trapped in the depressions.

The Water Table Factor.

On many coastal soils in Malaya, on many low-lying and flat lands, the water table is to be found within eighteen inches to two feet of the surface. It is almost incredible that under such conditions rubber should flourish.

The effects of this high water table are to be found in the development of nigger-headed roots, the waterlogged conditions of the soil making it impossible for the tap root and the laterals to pursue their normal course, with the result that their growth is arrested, the tips of the roots eventually swelling and assuming a knobby nigger-headed development. The trees, robbed of their anchorage, rapidly develop a tendency to lean, resulting in certain cases in their uprooting, occasioned by undue leverage exerted by the unbalanced crowns.

To bring about a lowering of the natural level of the water table and correct the tendency to lean, deep drains, five feet and more in depth, by three or more feet wide, twenty to thirty feet apart, are dug emptying into deeper main drains, to drain off the subsoil water and improve the adverse conditions obtaining in areas where such defects occur. The same principles hold good in the draining of swampy areas.

Soakaways.

Finally, mention must be made of the soakaway type of drainage practiced near the base of large cup-like depressions. In such formations a series of

deep drains are dug at close intervals to carry off the water, draining down the face of the slopes, before it can accumulate in the enclosed hollow of the basin. In this way it is possible to cultivate rubber on the flat areas at the base of such formations which would otherwise have reverted to swamp or even peaty conditions.

When peaty conditions exist it should be borne in mind that it is not an economic proposition to cultivate rubber, even after observing a system of intensive drainage. The trees are unable to obtain sufficient purchase in the mechanically weak structure of the subsoil, and are eventually levered out of the ground by the weight of the crowns.

It may reasonably be asked whether drains are not altogether superfluous where a system of green covers is enforced.

In the majority of cases they are still necessary ; it is true that a great part of the rainwater is soaked up by the channel ways made in the soil by the rooting systems of the cover ; but if silt pits are altogether absent, a valuable supply of soil water is unnecessarily wasted, a certain proportion finding its way to lower levels before it can be absorbed by the soil.

Where the water table factor has to be considered drainage is an indispensable and very necessary asset.

THE TAPPING PANEL AND TAPPING SYSTEMS.

Having briefly reviewed the more important factors which govern the growth of a stand of rubber and persist throughout the life of the tree, the tapping panel as the source of the raw rubber and the properties of the panel invite attention before considering the complex of factors influencing the modern methods of tapping.

External Characteristics.

The outward nature of the bark is very variable. In the majority of cases it will be found to be finely fissured ; in a few cases it may be almost smooth, and yet again, distinctly corrugated and corky, several millimetres of bark flaking off as the result of the activities of successive phellogens.

Internal Characteristics.

In an average bark sample taken from virgin bark the outermost zone will be seen to consist of a layer of cork about one millimetre thick, succeeded by a band of stone cells about two millimetres thick, passing into a complex of alternating rows of stone cells and laticiferous cylinders of varying depth, and culminating in the inner soft bast, one to two millimetres in thickness, from which stone cells are absent.

In renewed bark, which has developed from the millimetre and a half of virgin bark left on the tree after tapping, an authocyan zone, or red band, of tissue is to be found in the outermost stone cell zone, which generally disappears

at the end of eight years ; this feature is sometimes made use of as an index of mature tappable renewed bark.

The laticiferous system is arranged in a series of concentric cylinders, generally distinct from each other but occasionally connected with radial off-shoots. Each cylinder is split up by medullary rays, which are parenchymatous channels radiating from the centre of the wood and disappearing in the outer zones of the bark.

Between each pair of medullary rays rows of latex tubes, four to six in number occur, the tubes in each row touching one another in most cases, the individual rows being separated by the ground tissue of the cortex.

The general effect can be aptly compared to a number of upright cylinders of wire netting, one within the other, into which tiers of cartwheels have been carefully fitted at right angles, the spokes of the wheels representing the medullary rays, the solid structure of the wire the laticiferous cylinders.

The Main Elements of Interest.

A characteristic feature of Hevea bark is the very large number of stone cells, regularly arranged, presenting a type of bark uncommon to other forest trees.

The stone cell tissue represents a deposit of sugars converted into lignin in the cellulose walls of the parenchyma, or ground tissue of the bark ; the walls of this tissue are considerably thickened and radially fissured, producing concentric bands of woody gritty material.

Between these concentric cylinders are situate the cylinders of laticiferous tissue.

In Hevea the laticiferous system is not comprised of single isolated cells as in the fruit wall of the Papaya, nor can it be placed in the single branching tube system which occurs in Ficus.

The arrangement of the laticiferous cells belongs to the articulated type, in which the tubes are in contact, opening into one another as the result of the disintegration of portions of the cell-wall.

In longitudinal sections through the stem of a young seedling or a leaf stalk, near the junction of the bark tissue with the wood, it is possible to make out under the microscope rows of super-imposed rectangular cells, resembling a vertical row of bricks with dense protoplasmic contents.

Each brick-like cell contains a large central body, the nucleus, a structure which is very noticeable at this stage. The cross walls in these rows of cells gradually disappear, giving rise to a long tube at first irregular in outline but later straightening out. This is a laticiferous vessel.

If sections are treated with a caoutchouc solvent, such as Xylol, and then stained, the latex tube is seen to be a living element with vacuoles or liquid spaces and a protoplasmic lining containing many nuclei. The latex is contained in these vacuoles.

Laticiferous Patterns.

The arrangement of the tubes is never constant, but conforms to distinct patterns which vary from tree to tree.

The pattern of the laticiferous system varies not only in the relative distribution of cylinders in the soft bast, but also in the grouping in the bark as a whole. In some trees the proportion of laticiferous tubes in the soft bast is high, in some cases amounting to a dozen or more tubes in place of the usual four or five; in the former cases the soft bast is 2-3 mms. thick in contrast to the general average of 1 to $1\frac{1}{2}$ mms.

It is interesting to note that where the ratio of soft bast to hard stone cell bast is above the average the tree is in many cases a high yielder. As regards the grouping or banding of latex tubes, there is again considerable variation, as evidenced by the following types:

1. A series of groups of latex tubes, close together, between the bands of stone cells.
2. Groups of densely-banded laticifers, the central members being more widely separated than the marginal.
3. Types where dense banding of latex tubes is absent, only one to three rows occurring between the stone cell barriers.
4. Where dense banding obtains in the soft bast, but is replaced by a widely separated pattern in the hard stone cell zone.
5. Complete absence of laticiferous tissue from the soft bast region.
6. Very rare types where only few laticiferous tubes are found in the bark; in some samples as few as three cylinders are to be found.

It may some day be possible to gauge the yielding capacity of a tree by a microscopic analysis of the bark.

The Flow of Latex.

It must not be supposed that all tubes contribute to the production of latex when the tree is tapped.

The outermost zones of bark, sometimes extending to half the depth of the cut, yield little or no latex. In very exceptional circumstances the flow of latex occurs up to the limit of the outermost zones.

The failure on the part of the outer tissue to produce latex is not due to the absence of laticiferous cells from these zones, but to a lack of turgor pressure, and, to some extent, to the breaking up and interruption of the tubes by the outer groups of stone cells.

The greater part of the flow is thus contributed by the inner zones, the depth of tapping bearing a very marked relation to latex production; the deeper the tapping the greater the quantity of latex produced.

This increase is not ascribed to an increase in the diameter or lumen of the tube but to increased turgor pressure; the tubes do not appear to become any larger towards the cambium or dividing line between the bark and the wood.

The diameter of the latex tubes varies with the point of excision ; not only is there considerable variation in the shape and size of laticiferous tubes in one and the same tree, but an inconstancy obtains in the dimensions of one and the same tube which may be broader at some points in its length than at others.

It is extremely doubtful in view of this knowledge whether the size or lumen of a tube in cross section will ever be of any practical value in the selection of higher yielding strains ; it is thought by some, however, that it will be possible to determine high yielding types by the lumen of the tube.

The arrangement of the Laticiferous Cylinders in the Tree.

It might, on first thoughts, be reasonably supposed that the various cylinders ran vertically up and down through the bark ; a closer study of their anatomy, however, reveals a spiral arrangement of the cylinders, the tubes running from left to right, at an angle of 7° from the vertical.

It is for this reason that a left to right cut yields more latex, a larger number of tubes being opened according to the angle of the cut, the difference being more pronounced the steeper the cut—as much as 15% at 45° being recorded.

TAPPING SYSTEMS.

Before proceeding to review the different systems to be found in the East, it is necessary to outline in brief certain of the more important factors which have to be taken into consideration in this connection.

In the operation of tapping, parings of bark are removed from the trees, resulting in a flow of latex. It is convenient, therefore, to deal in the first instance with the thickness of the bark shavings.

The Thickness of the Paring.

Ceylon stands out in this respect above other countries in that very fine shavings find favour in contrast to the thicker parings in Malaya and the Dutch Indies. In the first-named country bark consumption varies from four to six inches per annum, in direct contrast to the nine to twelve inches elsewhere, the monthly consumption of bark not exceeding half-an-inch, as opposed to three-quarters and one inch per month in Malaya, etc.

It has been shown that the maximum flow of latex is to be obtained by removing two to two and-a-half inches per month, the ratio of rubber production for 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$ " of bark removed per month being 60.5, 77.5, 100, 101, (Archief, Jan. 25). The removal of $1\frac{3}{4}$ inches of bark per month is advised for alternate monthly, and 1" for alternate daily, based on the principle that the thicker the paring the greater the yield of latex. It is, however, very doubtful whether, taken over a period of eight years, the Ceylon system is not without its advantages ; it is possible that by limiting the tapping panel to a height of 24 inches from the ground over this period, an operation which is

rendered possible by the thinness of the shaving, a greater yield may be obtainable over this period than from a system where the height of the panel is increased to 36 and even 48 inches from the ground. It is generally admitted that the maximum production of latex is obtained at the base of the tree.

It is interesting to observe that as a general rule the thickness of the renewals in Ceylon is in excess of that obtaining for renewed panels elsewhere.

The Depth of Tapping.

Perfect tapping should aim at removing the bark down to one millimetre to a millimetre and a half of the wood ; with careful and deep tapping a greater yield is obtained than by shallow tapping, which fails to open the inner cylinders contributing the greater part of the latex to the flow.

The Height of the Panel.

When the girth of a tree, at four-and-a-half years in Malaya, and at the end of six years in Ceylon, measures eighteen to twenty inches at three feet from the ground the panels are marked out for tapping.

In Ceylon it is customary to commence tapping at twenty-four inches from the ground, tapping to the base of the panel with or without a change over ; this height attains a greater degree of constancy than in Malaya and the Dutch Indies, where the general average is eighteen or twenty-four inches for the first panel, the subsequent panel being opened at 36 or 48 inches, when the cut is on a half. When the cut is on a third of the circumference, the highest cut seldom occurs above thirty-two inches from the ground.

The Length of Cut.

The tapping cut may be on a quarter, or a third, or a half, of the circumference.

It has been found in practice that a single cut is more desirable than a number of cuts on the same panel ; the flow of latex and the actual yield of rubber per tree over a six to eight year period is greater for the single than the more than one-cut system over a limited area ; to countenance the latter system involves a set-back to the growth of the tree without contributing a proportionate yield of latex to balance its prejudicial effects.

In the past, full herring-bone, half herring-bone and full spiral systems were in favour, which omitted to take into consideration the rudiments of plant anatomy, the renewals being allowed to take care of themselves and but little attention paid to the flow of latex.

A half cut on young rubber, continued to the end of the second or even third renewal, when the tree will be nineteen or twenty-seven years old, is not without its advantages, a change to a third being introduced about this time. It is questionable whether it is advisable to open young rubber on a third, unless the trees are very backward in growth.

Change of Panel.

With the exception of Ceylon a panel is in most cases tapped down to the ground ; as soon as one side of the tree has been completed the panel is changed to the other.

In Ceylon, however, a change of panel is made in many cases once a year, and in certain cases every six months. It has been claimed for many estates that where the latter practice, known as the double change-over, has been adopted the change has resulted in a substantial increase in crop ; it is not so much the quantity of latex as the rubber content which is instrumental in bringing about this increase in yield. The increase is no doubt due to the fact that for four months of the year the rubber content has remained steady in the neighbourhood of 35% and over, instead of persisting at 30 to 25%, as is sometimes the case where the same panel is tapped over a period of years. The fact that one panel may yield more latex than the other must also be taken into consideration.

A double change-over system allows a period of six months' rest for each side of the tree, and does not drain on the same laticiferous cylinders over a number of years, thereby conferring a certain degree of immunity on the laticiferous tissues to Brown Bast. When contemplating such a practice it must be borne in mind that the tapping should be so arranged as not to drain on bark less than $4\frac{1}{2}$ years old ; a superimposed cut eighteen inches and less above the bark of a three to four year old renewal will not be without an adverse effect on the thickness of such a renewal, owing to the interruption and diminution of the food supply to those areas via the phloem.

The Tapping Interval.

The period of time elapsing between successive tapplings varies according to the system employed, which may be daily, alternate daily, third day, alternate fortnightly, alternate six weekly, alternate bi-monthly, etc.

In the past a daily system throughout successive years was in vogue ; this proved altogether too drastic for the trees, and resulted in a heavy incidence of Brown Bast and thin renewals ; this has been replaced by an alternate daily system which is to be distinctly preferred.

With the third-day system it has been found possible for the average estate to harvest 80% of the crop obtained by alternate daily tapping with a reduction in the annual consumption of bark and a smaller percentage of cases suffering from Brown Bast. It is highly probable that a third day system on a half, which is considered the equivalent of alternate daily on a third, will be the accepted system for the higher yielding strains of rubber.

Finally, an alternation of periodic tapping has come much to the fore in recent years. There is slight evidence to shew that an alternate fortnightly system of tapping, whereby one half of the estate is rested while the other half

is in tapping for fourteen consecutive days is not without its advantages in the case of young plantations.

Systems in which alternating periods of a month and six weeks are practiced may be said to compete favourably with the alternate daily system of tapping ; the same quantity of rubber is harvestable by either system. It is doubtful, however, whether a period comprised by a bi-monthly system of tapping can be considered economical, in view of the stimulation given to Brown Bast, and the falling away of the rubber content after the first month. " Brown Bast " is a decayed state of tissue at and below the cut, brought about by the degeneration of latex tubes and parenchymas as the result of over-tapping.

Rubber Content.

In conjunction with the frequency of tapping mention might conveniently be made of the rubber content, which assumes a rôle of the greatest significance when considering crop returns.

It is possible, by changing the interval of tapping, to increase the crop considerably by increasing the rubber content ; the rubber content of latex for this purpose should always be very closely watched ; unfortunately, it is a very variable factor.

On daily, alternate daily, and third day tapping, however, the rubber content may in most cases be said to fluctuate round 35% or three and a half pounds of rubber per gallon ; in the case of third day tapping the rubber content may be even higher.

On alternating periods of a fortnight to two months, as the result of a period of rest, the rubber content is very high for the first tappings, commencing at 50 to 40% rubber content, or four to five pounds of rubber per gallon ; the period over which a high rubber content prevails varies from estate to estate, a 40% content prevailing for as long as eighteen or more days. At the end of a month the rubber content has in most cases returned to normal, averaging 35% and less.

In alternating periods of rest and tapping it is often a matter of three to five days from the beginning of the month before the normal flow of latex is obtained, the cuts being re-opened in the afternoon a day or two before the change over from one half to the other half of the estate is made.

After taking the several factors into consideration, it might be reasonably supposed that an alternating period of twenty days would prove the most economical, as it is about this time, in many cases, that the rubber content falls away rapidly from the 40% to 35% mark.

The Angle of the Cut.

In the past a steeper angle appears to have been more in favour than the lower angle of to-day. The angle of the cut may vary from 25° to 30° to a steep cut at 45° ; the latter degree is however, uncommon, but still obtains to

a greater extent, perhaps, in the Dutch Indies than elsewhere. The arguments in favour of a steeper cut would appear to be the harvesting of a smaller percentage of scrap than otherwise ; the latex does not remain in the same quantity or for the same length of time as in the case of the flatter cuts.

The Nature of the Cut.

The surface of the cut may be flat, grooved or sloping. It is possible so to tap that the latex runs in a grooved channel, thus diminishing the tendency to spill over when the trees are wet, thereby effecting a considerable decrease in the quantity of earth scrap.

The point at which tapping commences is also of considerable importance. If the cut is opened half way instead of commencing at the top and proceeding to the bottom, starting with the basal half first, deeper and more careful tapping is to be obtained ; the tapper not infrequently hurries his work towards the base of a cut if the latex flow from behind catches up with the knife as is sometimes the case.

The Personal Factor.

The consideration of this factor enters very largely into the experimental side of tapping ; one tapper will obtain more latex from the same area than another, the quantity of latex being, in the main, related to the depth of the tapping.

The Sharpness of the Knife.

This very simple factor is often overlooked in estate practice. The best tapping was found on an estate in Java where each tapper carried two knives in the field, using the one as soon as the other shewed any tendency to bluntness. If every tapper were to carry a small whetstone and two knives, the knives being constantly oiled and kept in a case attached to his belt, a larger quantity of rubber would be harvested.

The Supervision Factor.

Additional supervision in the form of additional and special tapping conductors to overhaul every task at least once every two months means a considerable increase, not only in the percentage of first grade rubber but an increase in crop with a diminution in the tendency to wound the trees.

Wounding.

Hurried tapping resulting in driving the knife into the wood, so wounding the tree, results in the production of large woody burrs, which render a panel untappable for the future. The ill-effects of this burr formation can, however, be overcome if in their early stages the excrescences are shaved flush with the bark once a year, for the first four years of an eight year renewal. This operation curtails the activity of the nodular cambium and aided by the pressure

of the expanding bark a "lipping over effect" is produced, presenting a tappable panel; as much as .85 cms. of bark was found in certain cases over .4 cms. of wooden nodule.

Now that attention has been drawn to some of the many factors affecting the production of latex, a brief comparison can be made of the different systems of tapping to be found in different countries.

Tapping Systems in Different Countries.

In Ceylon perhaps the type system may be said to be alternate daily on a half spiral cut with or without a change over.

In Malaya a V cut on a half alternate daily enjoys more favour than any other system; the V cut has the advantage of effecting a saving in the quantity of earth rubber, the latex tending to spill over on a half spiral, which is possibly due to the more rapid flow of latex brought about by the removal of a thicker shaving.

In Sumatra, on the other hand, an alternate monthly system on a third cut may be said to enjoy considerable favour, while in Java alternate daily on a half or a third is common practice.

In the last three countries A.B.C. systems of daily tapping are common, whereby two-thirds of the estate are always in tapping as opposed to half the estate on alternate daily, A and B being tapped daily for a month, while C is being rested, then B and C, while A is rested, etc., each division receiving two months' tapping and two months' rest. An A.B.C.D. system, whereby three quarters of the estate is in tapping at once is a still further advance on this system. On superficial examination there might appear to be little to be said for such systems, but the practical results warrant consideration.

Unique Tapping Systems of Rubber.

It is not intended to review all the out-of-the-way systems which find their adherents to-day, but to call attention to the most practicable.

Two Superimposed Cuts.

On a Ceylon estate a very remarkable system, which consisted of third-day tapping on two superimposed V cuts, the cuts being eighteen inches apart, was employed, the upper cut giving 20% of the crop of the lower, the bark consumption being three inches per annum on either cut.

Daily Tapping on Opposite Quarters.

Such a system is not without its possibilities; it cannot be viewed with the same apprehension as the ordinary daily system, the latex being drawn from different areas; it is the equivalent of alternate day tapping on a half. It is possible that the crop harvested by daily tapping on opposite quarters would be greater than in the case of the latter system.

One Cut on a Quarter in Conjunction with a Half on the Branches.

This was seen to be carried out very effectively and apparently without any prejudicial effects on a very well grown tree, 42 years of age. The yield on the quarter cut was one hundred grammes or $3\frac{1}{2}$ oz. per tapping, and the total yield from the branches also one hundred grammes.

The Ideal Tapping System for Rubber.

It cannot be said that any one system as practiced to-day constitutes the ideal system, securing maximum crop with the economic minimum consumption of bark, and incurring maximum immunity from disease. It is possible, however, to evolve more than one ideal system which would require modification according to local conditions. The following might be taken as an example of such a system.

The First Tapping Period.

It is satisfactory to allow a six-year renewal for the first tapping period. In order to enjoy the full benefit of alternating periods of rest and tapping, to ensure the maintenance of a high rubber content, and to effect a compromise between the half inch per month system of Ceylon and the one inch of Malaya, reducing the height of the panel to more economic levels, a tapping system on a half cut, with a fortnightly or twenty days' tapping with a corresponding period of rest, with a bark consumption of 8" per annum, and a change of panel every six months—a change of panel resulting in the production of a thicker renewal and a prolonged rest for one half of the laticiferous cylinders—would satisfy such a set of conditions, the panels being opened at 18" and later at 27".

The Second Tapping Period.

During this period the same system might be continued with a few alterations; the tapping period might be changed to alternate daily or alternate monthly, if such a change were productive of more rubber, the upper storey of the panel being opened at 36 inches instead of 27, a renewal of eight years being afforded.

The Third Period.

Should the growth of the rubber be vigorous and healthy, the same system as for the second might prevail; if, however, there are any symptoms of deterioration, it would be wise to change the length of the cut to a third. This might be taken as the last change.

There is a certain school of thought which advocates opening the cut at a third from the time the rubber comes into bearing. With a few exceptional cases this cannot always be considered advisable, since the quantity of rubber harvested on a $\frac{1}{3}$ rd is generally only three-fourths of the crop harvested on a half; it cannot be said that a half-cut has proved too drastic an operation, as

exemplified by stands of rubber to-day; there are many trees on a half cut over twenty years of age which may still be considered to be in a flourishing state, even though they have been subjected to mishandling in their early stages.

THE MANURING OF RUBBER.

Foreword.

It is very probable that this all-important aspect of cultivation will for many years be but imperfectly understood. The misconceptions are, in a large measure, due to failure to grasp the significance of the law limiting factors, and to an incomplete knowledge of plant physiology. It is admitted that many backward blocks of rubber on heavy clay soils have not always responded to manuring; in such cases the limiting factor has in all probability been an insufficiency of soil water, the tree being unable to reap the full benefit of the manure and the increased production of latex being masked by the small quantity of water absorbed by the tree; had such heavy clays been silt-pitted, the circumstances might have been considerably altered. Again, organic manures are sometimes broadcasted over an area and allowed to remain on the surface; in view of the fact that a considerable proportion of the ammonia liberated on the breaking down of the protein escapes into the air, it is not a matter of surprise that the rubber should fail to show the desired improvement.

The living material of a plant cell—protoplasm—has been shown to consist, after the removal of water, of 55% protein, approximately 16% of which is Nitrogen; the mineral content generally totals 7%. From this it can be readily understood that the prospects of a manure mixture containing a preponderance of mineral as far as Potash and Phosphate are concerned to Nitrogen leave much to be desired.

With the exception of sugar-forming plants, such as Beet, etc., the proportion of Nitrogen to the more essential minerals, such as Potash and Phosphoric acid, will probably be found to be greater in most plant tissues. The vital and indispensable rôle of Nitrogen in the metabolism of plants is borne out by the fact that where a manure mixture is employed, from which the available Nitrogen has been omitted, it is difficult to detect any improvement in the growth of the crop concerned.

Nitrogen may justly be styled the limiting factor of plant nutrition, when considering the soil constituents. In very many instances the available Nitrogen content of tropical soils under cultivation would appear to have been more adversely affected than the mineral; in some soils not only is the available Nitrogen content too low, but the total insoluble Nitrogen content has been so depleted as to render a poor backward growth inevitable.

It is to be understood that the application of manure should be regarded as a correction of the deficiency of essential plant foods, which are chiefly embodied in the Potash, Phosphoric acid and available Nitrogen content of soils.

Virgin jungle and alluvial soils rarely, if ever, come under this category. The soils requiring correction are to be found among the heavily eroded types and those where the available food material has been seriously depleted by previous cultivation.

Practical Considerations.

That the aim and object of manuring should be misconstrued into an operation solely intended for increasing immediate yield is certainly unfortunate; the object should be to place at the disposal of the tree those elements which have been removed from the soil by leaching, erosion, etc., and so enable backward rubber, yielding 250 lb. per acre, to be placed in the course of time on the same footing as healthy, well-affiliated rubber giving 500-600 lb. per acre.

The difference between a stand of rubber on virgin soil yielding 500-600 lb. per acre and a clean weeded estate previously under coffee, coconuts, etc., yielding 200-300 lb. per acre, can in a large measure be ascribed to differences in the supply of available plant food; such differences can, in a measure, be obviated by suitable dressings of manure over a number of years.

It may be possible to bring about an improvement even in the case of well-grown rubber by the addition of manure, as evidenced by the very fine stands to be found where rubber has been regularly manured from the time of planting, and the markedly superior development of many trees in the vicinity of coolie lines.

Physiological Considerations.

It is significant that the three elements, Potash, Phosphorus and Nitrogen, which are drawn upon to a greater extent than others such as Iron, Aluminium, Silica, etc., are not present in the soil to the same extent as the materials for which the growth of the plant tissue has but little use. Were these three essential elements not so deficient in the average soil, there would be little or no need for manuring; as it is, most soils may be said to be deficient in Nitrogen, Phosphoric acid and Potash.

The Rôle of Nitrogen.

The Nitrogen in a soluble form is conducted to the leaves in the transpiration stream; it is possible to detect Nitrates and Ammonia salts in the leaves of plants, grown in the dark in water cultures where, by combination with carbonic acid and aldehydes, they are built up into the form of proteins in the leaf tissue. The soluble proteins and Amino acids are subsequently removed to the growing organs of the plant, where they become condensed to higher proteins and embodied in the construction of the protoplasm.

In every mature living cell a protoplasmic lining occurs in the form of a colloidal solution of proteins, carbohydrates, mineral salts, etc. An analysis of protoplasm has been shown to contain, after removal of water:—

Nucleo Protein	...	...	...	...	40%
Other Proteins	...	...	...	...	15%
Amino acid	...	...	...	...	1.5%
Carbohydrates and fats	...	...	...	...	24%
Salts ...	...	...	...	...	7%
Etc. ...	...	...	...	...	12.5%

It should be quite clear from the high percentage of Protein how impossible it is for plant growth—for the growth of a rubber tree—to proceed, if the available supply of Nitrogen is below the requirements of the rubber, as is so often the case.

The Rôle of Phosphorus.

A certain relationship has been traced between Phosphoric acid and fat and starch metabolism; this rôle however is of comparative insignificance when contrasted with the rôle of Phosphorus as it affects the nucleus.

The nucleic acid contains a very high percentage of Phosphoric acid, as much as 10%. It should be borne in mind that the nucleus is the central body of a plant cell, governing its powers of division, activity, etc. This possibly accounts for the marked and beneficial influences of Phosphates on root development. If there is an insufficiency of Phosphoric acid, the activity of the nucleus will be considerably curtailed.

The Rôle of Potash.

Finally, mention should be made of the rôle of Potash; this element is important as a co-enzyme, and is to be associated with the synthesis of carbohydrates; there is some evidence to show that Sodium can replace Potash in the physiology of the plant cell.

The Practical Results of Manuring to Date.

Very many experiments and trials have been made in the manuring of rubber. In backward rubber some excellent responses have been obtained by the addition of Nitrogen only, and a combination of Nitrogen and Phosphoric acid. It cannot be said, however, that the addition of Potash has induced any striking change in the growth of backward rubber; this is possibly due to the fact that there is at present a sufficiency of Potash in tropical soils.

Many manurial trials have likewise been barren of fruition; in many cases it is not necessary to investigate the conditions of the trial very far before realising that either the mixture was unsuitable and unbalanced, or a limiting factor such as soil water distribution, etc., had not been taken into consideration.

It is not proposed to serve up a mass of figures with which one is already familiar; suffice it to say that a formidable collection can be made by interested parties by investigating the results obtained in Ceylon and the Dutch Indies.

One set of figures which has received large publicity might however be set out here to advantage.

On the HAPM estates, in Sumatra, in 1919 the yield per acre in the experimental area was approximately 290 lb.; the rubber was very backward, as evidenced to-day by the stag-headed appearance of the original controls in the original trial blocks.

In 1922-23, as the result of manuring at the rate of 5 cwt. Sodium nitrate per acre, per annum, the yield per acre was as high as 533 lb.; where Ammonium sulphate at the same rate was applied every second year, at the end of the third year and following the second application the yield was 465 lb. per acre.

At the end of the first year following the Nitrate application, the increase in yield was reflected in a crop of 340 lb. per acre over 290 lb. for the unmanured controls.

To-day the canopy on HAPM is very vigorous, healthy and calculated to leave a lasting impression on the minds of those who have seen it.

It is interesting to note that manures with an acid tendency may cause a set-back and not always bring about an improvement in the rubber. The peculiar behaviour of the superphosphate and Ammonium phosphate blocks may be cited in this connection.

The Ideal Scheme.

In dealing with backward rubber it will be found in the majority of cases that it is the deficiency of available Nitrogen which is limiting the growth ; it would thus in all probability be more economic to supply Nitrogen only for the first two applications, to be subsequently followed by a mixture of Nitrogen and Phosphoric acid, manuring half the estate per annum, alternating the Phosphoric acid applications on each half by employing Basic Slag one year and Superphosphate another to counteract any adverse effects of acidity. Once the tone of the rubber has been improved, the manurial programme should continue ; otherwise the rubber will return in the course of time to its original status.

Manure Mixtures.

Nitrogen can be supplied in the form of Ammonium Sulphate and Chloride, Sodium and Calcium Nitrate, Calcium cyanamide and Urea in a readily assimilable form. It can also be supplied as combined nitrogen in the form of organic cakes such as Castor Cake, Blood Meal, etc., necessitating several chemical changes with the aid of bacteria before it can be taken up by the feeding rootlets as a soluble salt.

The Phosphoric acid takes the form of Superphosphate, Rock Phosphate, Fish guano, guanos, Basic slag, etc. ; the potash is supplied as Chloride or Sulphate.

It is obvious that the number of mixtures which can be made up from the above is very considerable. Before compounding a mixed dressing, certain points require attention, such as the choice of a manure supplying the maximum percentage of the element in question at cheapest cost, a manure which is

readily assimilable, and, finally, a mixture which can be stored on the estate without becoming too deliquescent.

Perhaps one of the most suitable dressings is to be found in Urea and Double Superphosphate or Basic slag at the rate of 180-200 lb. Urea and 100 lb. Phosphate per acre, supplying 84 lb. Nitrogen and 42 lb. Phosphoric acid. Admittedly, Urea is not absorbed to the same extent by the soil as Ammonium Sulphate, and might thus more easily invite the possibility of being leached out by rainwater, but in view of the small quantity scattered over a wide area of rooting systems it is doubtful whether such an objection is valid.

The Mode of Application.

If a cover is in possession of the soil the cover should be rolled up and the manure broadcasted over the bare strips; the cover should be rolled back, after an interval of ten days to three weeks has elapsed from the time of application.

If cover is absent the weeds or slashed grasses should be removed before manuring is contemplated.

In Ceylon a common method of application consists in broadcasting the manure down the rows of rubber, leaving a 3-ft. margin either side of the tree. The manure is then envelope forked or raked into the soil; on flat land in Malaya and the Dutch Indies it can be disced in with a light bullock harrow which rides the roots without much difficulty.

In the case of very soluble compounds such as Urea, Ammonium Sulphate, etc., it is sufficient to broadcast the manure and dispense with subsequent forking.

In the Dutch Indies it is not uncommon to find a shallow circular trench at 3-5 ft. from the tree, a foot to eighteen inches wide, in which the manure is changkollod into the soil. After one month to six weeks from the date of application this trench may be found to be literally packed with the white wiry feeding rootlets of the rubber.

The Time of Application.

This has a very decided influence on the success of the dressing. If the effects are to be shown in the shortest time possible—everyone should aim at this—the manure should be in the ground before the wintering period, when the foliage of the year's growth is shed and new leaves put out.

An increase in yield is in most cases to be reflected six months after the application; in others the interval between the application and an increase in yield may be longer.

If, on the other hand, the rubber is manured after wintering little or no increase in yield is to be detected till six months after the following wintering period; this is only natural, since the increase depends on a larger production of foliage for the synthesis of additional raw material which controls the quantity of

rubber manufactured by the trees ; once a tree has wintered, there is little or no addition—except in rare cases—to the foliage production for the current year.

Where the mixture is applied before wintering very striking differences are to be found in the appearance of the canopy ; the tree becomes densely affoliated ; the foliage is a darker green, and the shade thrown by the trees very noticeable, leading to a greater surface development of chlorophyllous tissue capable of synthesising the many organic compounds vital to the growth of the rubber.

It is not altogether true to say that there is no effect on the appearance of the rubber as the result of manuring after wintering ; the foliage becomes a darker green, the shade becomes marked ; these differences are not, however, to be ascribed to an increase in the production of leaf, but to the fact that the changed state of the canopy does not act as so good a light filter as the paler, foliage.

The Exhaustion Factor.

This is a point which must not be overlooked, particularly in cases where dressings of Nitrogen only are supplied.

Analyses of the majority of soils show a sufficiency of plant food to last for many years without having recourse to artificials. But, unfortunately, only a very small percentage is an available form ; the greater part is locked away in an insoluble complex.

As the result of an increased growth rate following on the addition of Nitrogen, the reservoir of available food becomes more rapidly exhausted than would have been the case had no manure been added. It has been shown in other branches of agriculture that over a period of years this exhaustion of the available soluble mineral content of the soil reacts adversely on the growth of the crop cultivated, unless the effects of the exhaustion are counteracted by the addition of the necessary mineral constituents.

It is quite possible that such circumstances may arise in the case of rubber ; if, however, balanced manures are employed the chances of history repeating itself should be negligible.

Miscellaneous Considerations.

These may be styled, for want of a better name, bark and canopy insurance ; the subject of Brown Bast is also discussed in this connection.

Bark Renewals.

In view of the severe methods of cultivation to which *Hevea* has been subjected in the past, it is not a matter of surprise that many of the present bark renewals on parts of estates are dangerously thin.

As the result of the loss of top soil removing untold quantities of available food, there is in many cases an insufficiency of soil material to enable the tree to produce a satisfactory renewal.

It is not to be wondered at that the yield of once good rubber should drop from the five hundred mark to below 300 lb. per acre ; in such cases the renewals have been so thin as to preclude the possibility of harvesting normal crops and have necessitated a change in the tapping system, involving a shortening of the length of the cut. Such cases stand in need of manurial correction.

Leaf Diseases.

In cases where leaf fall occasioned by a parasitic fungus, such as secondary leaf fall caused by *Phytophthora Faberi* in Ceylon, *Oidium* in Java, *Fusicladium* in S. America, is encountered, it becomes necessary to manure the rubber not only to increase the resistance of the rubber by accentuating the tonus of the protoplasm, but to enable the tree to produce a second crop of leaves without undue exhaustion of its natural reserves.

Secondary leaf fall in Ceylon and Java is far more serious than one might at first suppose. *Phytophthora* attacks the developing fruits, causing pod rot, and subsequently the leaf stalks and mature foliage, leading to an abnormal fall of leaf ; cases are known where a decrease in crop can be attributed to the incidence of this disease. *Oidium*, on the other hand, attacks the young foliage after wintering, and is for this reason more difficult to control.

Spraying the foliage with mixtures of lime or soda and copper sulphate may bring about a reduction in the incidence of leaf disease ; but in view of the many practical and physiological difficulties it is to be questioned whether by increasing the vigour of the tree, it may not be possible to detract very considerably and more effectively by such means from the havoc in store for affected rubber left to take care of itself.

It may be said that in infected areas the loss occasioned by leaf parasites need not necessarily furnish undue cause for alarm, if the rubber in question is suitably manured. Not only is the incidence of leaf disease less marked in manured as opposed to unmanured rubber, but the trees are enabled to put on a second crop of leaves without draining the natural reserves of the tree.

On one estate in a weakly affoliated area suffering from *Oidium* it was very interesting to note the difference in the manured and unmanured areas. In the former the trees were well affoliated and had suffered very lightly from loss of leaf ; *Oidium* was present on the young leaves and there was evidence that many leaves had been attacked but had not succumbed to the disease. In the latter secondary leaf fall was pronounced and the young foliage presented the crinkled, shrivelled appearance together with the irregularly serrate margin associated with *Oidium*.

Brown Bast.

It is doubtful whether a relationship can be traced between the incidence of Brown Bast and manuring ; certainly the outer dead areas of the bark are more readily flaked off as the result of the application of manure ; but whether

the resistance of the laticiferous tubes is to be increased in the same way as in the case of the foliage still remains to be decided.

Without enumerating the several theories which have been advanced from time to time to explain the causes of Brown Bast, which is perhaps the most serious disease of the tapping panel to-day, it is sufficient to say that most scientific men have come to regard Brown Bast as a degeneration of the laticiferous and cortical tissues, resulting from the excessive removal of water from the tree by tapping.

It can be combatted very easily by increasing the interval between the periods of tapping and isolating the affected zones at once with a knife by a cut to the wood; this prevents its spread to the roots and elsewhere. If taken in time, by ensuring a regular inspection of every tree at least once a month, there should be no need to take an affected tree out of the tapping round; instead of scraping away the waterlogged tissue studded with small areas of red and brown moribund cells, it is sufficient to remove it in the course of tapping.

If neglected, the disease spreads to the roots and through the untapped panels; the latex flow ceases and nodules develop which may subsequently develop into irregular masses of wood in the bark—in some cases more than a foot long—rendering the panel untappable for the future.

The East as a Whole.

In the majority of cases it may reasonably be said that there are very few estates where it would not be possible to improve the growth of the rubber and secure larger crops on some area or other of the property in question by manuring. It is more the exception than the rule to find stands of rubber vigorous and productive throughout the length and breadth of the property. Such cases no doubt occur where the rubber has been planted direct from virgin jungle and where the available material has either been rightly conserved or not sufficiently depleted to evidence the effects of malnutrition.

In many cases the canopies are weakly developed and sparsely affoliated; to induce the necessary vigour one is obliged to have recourse to manuring. Where manure is needed it is unreasonable to expect the renewals to be satisfactory, except perhaps by an alteration of the tapping system, aiming at a reduction in the length of cut. By increasing the length of time of the renewal a tappable panel may possibly be obtained. Not only are large quantities of rubber forfeited, however, by reducing the length of the tapping cut, but the opportunity of harvesting larger crops had the growth rate of the tree been increased, has been missed.

Finally, where financial considerations are the limiting factor it might be profitably borne in mind that a dressing of so small a quantity as one cwt. of Ammonium Sulphate or $\frac{1}{2}$ cwt. Urea per acre is not without its advantages. It is possible that such a practice may come to be regarded as a part of estate routine.

THE STRAINS OF RUBBER.

Such an expression may be an unhappy one, but it may be considered convenient to classify rubber under low-yielding and high-yielding strains.

On every estate there is a considerable variation exhibited as regards the yield of the individual tree ; it is possible to find large healthy trees yielding 2 lb. and less of rubber per annum, while their less numerous neighbours yield at the rate of 30 lb. of rubber per annum.

These high yielding qualities are in no way to be related to the size of the tree. Many trees of dimensions well above the average as regards girth, branching system and spread of canopy, yield very little latex ; on the other hand, seemingly dwarfed trees are to be found in the high yielding category.

It should be noted that very many of the high yielding types are not above the average as regards the size of the individual.

The Characteristics of the High Yielding Tree.

It is of interest to record a few observations which have been remarked from time to time by practical men in this connection.

Leaf Type.

Some have associated the factor of high yield with the size of the leaf. One school would associate high yield with a tree possessing a large type of leaf, with few and large leaves, another choosing to regard the small leaf type with many small leaves as indicative of high yielding qualities.

Yet others have associated such properties with the shape of leaf, speaking of high yielding trees with long pointed leaves as " the female tree."

The Branching System.

It is interesting to note that many high yielding trees have a very definite candelabra style of branching ; the significance of such a habit is, however, obscure.

The Parasol Habit.

Mention must also be made of a peculiar type of crown, resembling a collection of grouped parasols at the top of the tree.

No doubt there are many other factors linked in the mind of the individual with the high yielding properties of certain trees, but in the present state of our knowledge no significance can be attached to any of the factors enumerated above.

The Laticiferous Complement.

By this term we understand the number of laticiferous cylinders in the bark. In this connection there would appear to be a distinct positive correlation between high yield and a large number of laticiferous cylinders ; the coefficient of correlation is $\pm .5$.

This does not mean that every high yielding tree has a large number of laticiferous cylinders ; some have a low complement, but such would appear to be the exception rather than the rule.

As a general rule one comes to associate high yield with this factor more than any other ; it is interesting to observe that the pattern of the laticiferous system in high yielding trees is generally very densely banded ; between two rows of stone cells there are generally several rows of laticiferous cylinders crowded together rather than a few and widely separated.

The number of laticiferous cylinders varies considerably in a high yielding tree ; in some it is common to find 18-20 rows, while others have as many as 50 and more.

It is not known whether there is any correlation between the ratio of soft to hard bast in the bark, but an unusually wide strip of soft bast next to the wood 2-3 mms. in thickness, as opposed to the 1 mm - 1.5 mms. in the average tree, is not uncommon in a high yielder. The unknown quantity embodied in the activity of the protoplasm of the latex tubes varying from tree to tree, as regards the synthesis of latex, should not be overlooked as a determining factor of the yield of a tree.

Selection of Mother Trees.

In seeking to propagate from a high yielding Mother tree it is well to bear in mind certain desirable features before making a final selection. It is not always possible, however, to find a combination of the desirable characteristics in one and the same tree ; nevertheless, attention can be paid to certain features with advantage. The ideal Mother tree, as far as the panel is concerned, might be considered to be one possessing thick succulent bark (1.5 cms. thick), a large number of laticiferous tubes of a banded pattern, and enjoying a flow of latex up to the outer edge of the bark ; such trees do exist, and can be found after long and patient searching.

In addition to the above, mention might be made of certain properties of which the value is still obscure, as, for instance, the size of the Mother tree, its susceptibility to Brown Bast and peculiarities of growth.

The Size of the Tree.

This is a factor on which there is a considerable difference of opinion. ,

In a field of rubber is a very large tree to be regarded as owing its superior qualities to having struck a better patch of soil, having enjoyed better lighting conditions, etc. ? Or, is the size of the tree and the greater vigour to be regarded as an inherent quality, genotypic, as opposed to phenotypic ?

One cannot help but incline to the genotypic claims, in view of the fact that in fields of average rubber where the soil is poor it is possible to find these well-developed specimens ; again, seed from such trees may give rise to more vigorous and larger seedlings in the nursery, the differences in growth rate among seedlings from seed germinated at the same date being very marked.

It is not always wise to select these abnormally developed trees ; it is possible by concentrating on the smaller type to obtain a larger stand per acre of high yielding material which will be reflected in a higher yield per acre.

Susceptibility to Brown Bast.

There are some who would no doubt discard a Mother tree which had been shewn to be susceptible to Brown Bast. In view of the fact that many of the high yielding trees suffer at one time or another from this "disease," it is not altogether wise to discard them ; if scientifically and correctly treated, by a change of tapping system and by isolating the diseased area with a cut to the wood, Brown Bast can be kept well under control.

It is only natural that an 80 lb. tree, giving over 600 cubic centimetres of latex per tapping—equivalent to two large coconut shells, or three aluminium cups—should be liable to Brown Bast at some time or another ; it is possible to reduce the incidence to a minimum by third day tapping on a half, which is the equivalent in yield of alternate day on a third. In fact, it is not unlikely that the future tapping system of high yielding strains will be based on a third day, as opposed to the alternate day practice now in vogue.

Peculiarities of Growth.

Whether a tree should be discarded owing to the presence of peculiar features, such as twisted stems, ridged panels, etc., is certainly problematical.

The more unpropitious features, such as a tendency to develop dormant buds, which may appear as large wooden nodules in the bark, in view of their interference with tapping, might very reasonably rule a tree out of selection.

The Methods of Recording Yields.

Having selected the Mother trees for closer examination after the first few preliminary tests have been completed, certain hard and fast methods are observed for recording the yield per tapping and gauging the approximate value of the tree.

Weights of Samples.

One method involves the coagulation of latex in the cup with Acetic or Formic acid, the coagulum being labelled and taken to the factory, where it is milled and subsequently weighed.

This is perhaps the most accurate method, although a trifle laborious.

The Quantity of Latex.

The alternative method is to pour the latex into a graduated cylinder and record the number of cubic centimetres, the rubber content being determined by means of a metrolac or by coagulating a sample.

For purposes of general calculation the rubber content may be taken as 35%, unless the metrolac readings, etc., are to the contrary, one hundred cubic centimetres of latex containing 35 gms. of rubber, 28.35 gms. being the equivalent of one ounce of rubber.

To obtain the actual value of the tree it is necessary to take the readings of the rubber content for every tapping. Where several Mother trees are under observation it is a matter of difficulty to perform such an operation; the readings are accordingly taken twice to four times a month.

The Value of a Mother Tree in Relation to its Environment.

This will be determined by the soil, the moisture factor and cultivation.

The Soil.

Rubber growing on a poor soil—a washed volcanic loam or a weathered lateritic hill side—cannot be expected to yield the same quantity of latex under such ill growth conditions as on a virgin jungle formation, where the fertility of the soil is reflected in the vigorous growth of the rubber.

This feature is not always fully recognised; in many cases a Mother tree on a poor soil giving 20 lb. of rubber per annum may be capable of yielding 30 to 40 lb. and more on a good soil; this point should be borne in mind when making a comparison of Mother trees from different sources.

Moisture Content.

It should also be remembered that one tree may yield more latex than another, as the result of peculiar local conditions or environment. In districts where the saturation point of the atmosphere is considerably higher than in others, not only is this to be reflected in a larger production of latex, but also in the rate of flow; the trees may be said in certain cases to “drip” under such conditions.

Again the soil water content has to be taken into consideration. A tree on a slope may give less latex than a similar tree in a valley, the valley enjoying the advantages of maximum percolation of soil water, and yet be a more valuable Mother tree.

Propagation.

In practice the higher yielding strains can be propagated by seed from Mother trees, seed from budded plants, seed from isolated gardens or vegetatively by marcotting and by bud-grafting.

The very least that can be reasonably expected of a responsible party is to plant seed taken from individual Mother trees. It is still not uncommon, however, to find the seed selected *en masse* from a collection of trees in high yielding areas, including low yielding as well as high yielding strains; such practice is certainly unfortunate.

Seed Collection.

Every tree has a distinctive pattern, to which all the seeds from the same tree conform ; the marking of the seed is so distinct that given a seed from any one Mother tree it is possible to pick out from a massed collection the seeds of the Mother tree in question.

If the pods are allowed to burst, scattering the seed to varying distances from the Mother tree, it is still possible to recover them by giving out the pattern to a couple of coolies who walk through the rubber and collect the necessary type.

It is more convenient, however, to wait till the pods have split on the tree, the brown face of the seeds showing through the cracks, and remove them from the tree before bursting.

If this is done satisfactory germination is to be obtained ; but should the pods be cut off before the walls are shrivelled and partially split the immature seed, with a pale pink or light brown face, cannot be expected to germinate.

The method of collecting while on the tree is successfully carried out in the Dutch Indies.

Seed Transport.

In transporting seed over long distances, as, for example, from one country to another, special precautions have to be taken to ensure germination on arrival.

The seeds are accordingly packed in powdered charcoal ; it is as well to moisten the charcoal ; if the seeds have been disinfected there is little or no danger of contracting mouldiness.

Dry sawdust has also been successfully used as a packing material ; in this case it is not altogether wise to moisten the sawdust, which is unnecessarily encouraged to ferment.

The Principles of Seed Selection.

It should be borne in mind at the outset that in this matter we are still working in the dark, and shall continue so to work until the behaviour of high yield as a chromosomal factor has been definitely determined.

It may not be impossible to cross one high yielding tree with another and yet obtain low yielding offspring.

Chromosomes.

It is not remiss at this point to make brief reference to such bodies.

The activities of every living plant cell are governed by a spherical prominent body suspended in the protoplasm known as the nucleus. The reticulate structure of the densely staining plasma of this body undergoes a complex of changes, when the germ cells are being laid down in the tissue of higher plants.

The spireme or thread-like stage of chromosomal material evolved from the dense reticulum is divided into a number of chromosomes which assemble on an equatorial plate and subsequently withdraw to opposite poles of the nucleus ; from one nuclear body two nuclei are generated, one at each pole of the original nucleus.

In the first division certain very important changes take place ; the number of the chromosomes is halved, the chromosomes from the father migrating to one pole, from the mother to the other pole. This reduction in number is a necessary preliminary for the successful fusion of future male and female chromosomes ; if, for example, a plant with 12 such bodies did not undergo such a reduction division the next generation would contain 12 from the father and 12 from the mother, making 24 in all ; the subsequent generation would contain 48 ; such a state of affairs would result in a considerable disturbance of equilibrium, as the chromosomes are the bodies carrying the factors for heredity, resulting in most cases in sterility.

Without embarking on the operation of dominant, linked, lethal factors, etc., suffice it to say that the mechanism of these chromosomal bodies must be understood to be able to gauge the value of selected seed, which is governed by the conditions of the fertilisation, as regards its subsequent behaviour.

The Results Obtained in Practice.

High yielding strains have been employed to fertilise other high yielding strains. For this purpose bamboo stands have been built around Mother trees, enabling workers to reach different parts of the tree and carry out artificial pollination.

For this purpose the larger female flower has been fertilised by introducing the staminal column of the male flower, and then plugging the mouth of the corolla with a small piece of cotton wool and squeezing the whole. In most cases cross pollination as opposed to selfing has met with greater success.

In some cases muslin bags have been employed as a safeguard against the entrance of foreign pollen before and after pollination. Provided, however, the flower shoots are kept under close observation and fertilised as soon as the tips of the corolla begin to bend back, the flowers being prised open with a pair of forceps and a plug of cotton wool being inserted after pollination, muslin bags need not be used. Trees bred on such lines have yielded at the rate of 12 lb. and over per annum at seven years old, as opposed to ordinary seed giving 2-3 lb. of rubber.

There is every possibility that seed from such sources will give rise to offspring yielding at the same rate as the original mother trees.

Artificial pollination is naturally a laborious and tiresome process. The same ends are to be achieved by planting out budded plants from high yielding Mother trees in isolated gardens away from all rubber and allowing natural pollination to take its course.

The next best seed are to be obtained from areas of budded rubber, surrounded by the original plantings. Bees, insects, etc., responsible for pollination cannot help but carry the pollen from one budded tree to another ; the significance of contamination from outside rubber is not, perhaps, as great as one might at first suppose.

Finally, it is interesting to note that areas planted up with seed selected from high yielding Mother trees, surrounded with indifferent rubber, show a considerable increase in productivity over the unselected ordinary rubber.

But in view of the high percentage of contamination from low yielding strains such areas cannot be reasonably expected to compare with the offspring from isolated and massed areas already mentioned.

Marcotting.

Before passing on to consider the problems of bud grafting it is convenient to refer briefly to an operation known as marcotting. A marcot is a part of a branch, and therefore cannot be expected to develop other than the characteristics of a branch ; the significance of this phenomenon is dealt with in budded rubber.

A ring of bark, three to six inches long, is removed all the way round a branch of a Mother tree or the shoot of a budded plant, the exposed wood being covered with cow-dung, earth, fibrous material, etc., and kept in a moistened state by the addition of water. After a while roots develop from the pericycle of the living bark, growing down into the cow-dung bandage ; when this abnormal root development has reached a certain stage the branch is cut off and can be planted in the field as a stump, subsequently developing into a tree.

Unfortunately, such a tree is without a tap root ; although some of the laterals function as a joint tap root, trees of this nature are liable to contract a lean and be subsequently uprooted.

THE PRINCIPLES OF BUD GRAFTING.

Perhaps the most apt description of budding was that furnished on one occasion by a Chinaman who described the process as " changing the bark."

In the process of budding a piece of succulent branch bark is grafted from a high yielding tree on to a suitable stock and allowed to develop into a budded tree, the shoot arising from the bud patch callusing over the cut surface of the stock.

Although the Mother tree may have been a very high yielder this does not signify that the budded tree will of necessity possess similar high yielding properties. From 250-300 clones originally made in Sumatra, only 8-10 have to date yielded at a higher rate than rubber grown from unselected seed ; several have given yields below those obtaining for unselected seed.

The high yielding factor in a budded plant is extraordinarily complex.

Mention need be made only of the laticiferous complement and the activity of the cambium in this connection. In the latter case the cambial activity as influencing the production of laticiferous cylinders may possibly be found to vary according to the height from the ground at which the bud from the Mother tree is taken ; it is possible that the qualities of the cambium of a bud at one point on the tree may differ from those of the cambium at another point, the production of laticiferous tissue being regulated accordingly.

As regards the type distribution of the laticiferous cylinders in Hevea, attention may be drawn to two systems in particular. In one system the decrease in the number of laticiferous cylinders in the branching system when compared with the stem is not as marked as in the other and perhaps commoner type, where a considerable decrease is apparent. In view of the fact that a budded plant is a branch grafted on to a stock, this is a very important consideration ; if in a bark sample from a branch the laticiferous complement is found to be high, there should be a reasonable chance of the clone—a group of trees propagated from a Mother tree—being proved to inherit the high yielding qualities of the Mother tree.

At this point it may be observed that the planting out of a clone on a large scale, without previous tapping of the clone, etc., may be attended with disastrous results.

The Choice of Material.

In selecting material for budgrafting either the top shoots of the tree, from which the bark can in many instances be readily peeled, or succulent shoots arising from pruned branches may be employed. The pollarded shoot is much easier for practical purposes, producing soft, succulent bark with many buds.

The Operation of Budding.

Several methods have been employed, but perhaps the most convenient is that known as the patch method.

Two vertical and one horizontal incisions are made in the bark of the stock, the latter at 3-6 inches from the ground ; the bone end of the budding knife is run along the cuts to ease the flap, which is subsequently peeled from the top downwards. The bud patch is inserted, the flap being replaced, and secured with a bandage of waxed cloth or plantain fibre.

After twenty days the bandage may be removed and the bud patch examined; if, on scraping, the outer zones of the patch are found to be still green, the bud patch may be considered to have taken ; after another ten days the young plant is cut back to within 6 inches of the bud patch to enable the bud to swell and subsequently burst.

Miscellaneous Considerations of Budding.

These embody some of the more important considerations pertaining to the bud and to the stock on which the bud is grafted.

Considerations of the Stock.

These are tabulated for the sake of convenience.

(1) The soil is often banked up against the collar of the young plant ; if this is not scraped away, inclusions of dirt which tend to reduce the chances of a successful take are difficult to avoid.

(2) It is as well to make the incisions 6-12 plants ahead of the plant you are budding ; this allows the latex to coagulate ; not only does the flap peel more easily under such conditions, but the latex from the incision is prevented from streaming across the cambium ; where the latex is allowed to flow over the freshly-exposed wood it is impossible to secure a successful union of the cambium of the stock and patch.

(3) Except one is working with expert coolies it is as well to employ one to cut the buds and the other to attend to the flap. The slime tissue of the cambium dries out very quickly if exposed to the air ; if this tissue is seriously impaired a junction of patch and stock is rendered unnecessarily difficult.

One man should cut the bud and remove the sliver of wood attached to the bud patch only when and not before the other is ready to peel the flap. In this way the minimum chance is afforded the cambium on both stock and patch to dry out.

The bud patch is placed on the flap and the whole closed as quickly and gently as possible.

(4) If the outer flap is pressed too firmly the patch may slip and so tear the cambial tissue ; this can be avoided by placing the finger against the top and not the bottom of the flap, holding it in position without causing any disturbance until the whole has been bandaged and the operation completed.

(5) There is no need for the patch to fit exactly into the incisions on the stock ; the margin of wood which is left uncovered when a patch is cut smaller than the flap is soon callused over ; an exact fit often results in the inclusion of coagulated rubber along the margins, leading to a dying off in these areas which may subsequently have an adverse effect on the development of the patch.

(6) The application of cow-dung over the bandages, with the addition of fern shades, considerably increases the chances of success, inasmuch as protection of the patch from excessive insolation is thereby afforded.

Consideration of the Bud.

On examining the budding material at one's disposal it is not difficult to pick out a number of leaf scars, which take the form of studded crescents or horseshoes. The leaf scars are sometimes widely spaced ; but in the majority of cases some portion of the budwood will contain a cluster of scars in whorls. Above these scars it is possible to detect a brown circular bud, occupying the axil of the original leaf stalks now represented by the leaf scar ; the bud may be raised or depressed.

On examining the inner face of the bark these brown circular buds on the outside can be recognised as distinct areas of green tissue standing out in relief from the surrounding bark. Flower shoot scars which might, on external examination, be taken for buds are easily detected inasmuch as the distinct green areas of a leaf bud are absent on the inner face of the bark.

The patch of bark with a bud is removed from the budwood with an attached sliver or tongue of wood, to prevent damaging the cambium. When this is removed before insertion on the stock the buds become visible. Should the bud contain a wooden core it is in most cases valueless; if brown and dead it is quite useless; even if hollow it should be rejected.

Occasionally a soft appendage of tissue emanating from a bud is to be found; this should be carefully cut away before making the graft.

On a budwood shoot employed for budding there is in most cases a certain proportion of green as well as brown bark; the former breaks very easily and can be rejected. It is possible, however, to be successful with buds from green as opposed to brown bark, provided the budding is completed as soon after the cutting of the budwood as possible.

Even the buds in the axils of the leaves still present can be employed; but in many such cases the inner face of the bark is channelled and arched at the point of issue of the leaf stalk, a condition which considerably impairs the chances of a take.

Treatment of the Budwood.

Provided budwood can be put out within one to two days after cutting, it is not always necessary to wax the cut ends to prevent evaporation. If, however, the budwood cannot be employed at once, it is as well to wax the cut ends where the budwood has to be conveyed over appreciable distances, subsequently sawing off the waxed end at the base of the branch and transferring to a kerosene tin containing two to three inches of water. The water should be changed daily, the kerosene tins being kept in a shed away from the sun and the budwood covered with sacking, plantain sheaths, etc. In this way it is possible to keep the budwood alive for ten to fourteen days. When in the field it is still advisable to cover the tins with sacking, etc., to prevent undue evaporation and exposure to a hot sun.

The Place and Time of Budding.

The operation can be performed in the field or in the nursery. Budding in the field on to plants grown from seed at stake is not to be advised for several reasons. Supervision is very difficult, unnecessary labour is expended in going from plant to plant, and the same degree of success is not always to be achieved as in the nursery, owing to the exposed conditions of the budded plant. The evaporation, etc., can, however, be cut down by the use of cow-dung and fern shades.

It is preferable to bud the plants in the nursery, to be subsequently put out in the field, the plants being originally spaced 18 inches to 2 feet apart, to allow a vigorous growth and sufficient space for budding. The special advantages of additional shade, ready and easy control, minimum labour are in favour of performing the operation in the nursery.

As regards the time of budding, the most suitable months vary in different countries. As a general rule budding should synchronise if possible with periods of active growth and even rainfall ; it is not desirable to bud in Monsoon weather. Apart from the difficulties of handling the material in a downpour of rain, complications follow in the matter of rotting patches and failures.

Again, the material should not be budded out in periods of drought ; it is very difficult to secure a take under such conditions.

Finally, it is advisable to bear in mind the question of disease. In Ceylon, for example, it is as well to secure more than a foot to eighteen inches of young shoot before the beginning of June ; an attack of *Phytophthora* may kill back the shoot and arrest its development.

The Choice of Stock.

It is just as important to take special pains in selecting the stock as it is in choosing the Mother tree.

It was at one time thought that if a bud was made on a low yielding stock the latter would exercise a marked prejudicial influence on the yield of the budded plant and *vice versa*. This, fortunately, has been proved to be incorrect, the area over which the influence of the stock is felt being in most cases confined to within one foot to eighteen inches of the junction of bud and stock. In most budded plants the yield may suddenly fall or rise when the tapping cut approaches within one foot of the junction, according to the nature of the stock; the decrease can be generally associated with a low yielding stock, with a low complement of laticiferous cylinders and *vice versa*. Above this region the yield of the bud would not appear to be affected ; one of the characteristic features of a budded plant is the uniformity in yield at any point on the cylinder of the budded tree.

In the case of a tree grown from seed the yield at 2 to 1 ft. from the ground is considerably greater than that at ten feet ; in a budded tree the yield is about the same at both points due to the cylindrical nature of the growth.

It is thus apparent that the selection of the stock need not be governed by the high or low yielding capacity of the Mother tree from which the seed furnishing the stock was obtained ; the selection should, however, be governed by the vigour of the stock employed.

The growth rate of a budded plant, made from a budgraft on an average seedling is behind that of material where vigorous stocks have been employed. The more pronounced the vigour of the stock, the greater the growth rate and the girth of the budded tree, which are to be reflected in a greater yield of

rubber per tapping ; such phenomena are no more than what one would naturally foreshadow when dealing with grafted material.

Finally, the age and size of the stock have to be taken into consideration.

The best results are to be obtained by budding on to succulent stocks 9 to 18 months old ; the greater the diameter of the stock, within limits, at the time of budding, the more rapid and more marked is the growth rate of the bud.

Attempts have been made to bud on to old trees ; for this purpose a small area of bark is stripped near the base of the tree and sprayed with wax, the bud being made on the succulent renewed surface. It may be possible to develop budded trees successfully along such lines, but the callus formation over the large surface of stock exposed by the cutting back of the tree to the bud will be attended with difficulties.

Apart from stocks of *Hevea brasiliensis*, *Hevea spruceana*, *collina*, etc., have been employed ; it is possible that such stocks may develop normally in water-logged areas which are not favourable to the growth of *Hevea brasiliensis*, the species cultivated throughout the East.

Planting out in the Field.

After the elapse of thirty days from the time that the bud was made, the budded plant may be cut back, or the bark ringed six inches above the patch, and the crown of the young plant removed at the same time ; this stimulates the bud to swell and burst. The plant may be left in the nursery for another fortnight and then planted out as a doormat bud or left until the green bud is showing from the patch. In the majority of cases the budded plants are planted out only when a green bud has made its appearance.

The planting out of a dormant bud, however, is probably to be preferred, inasmuch as the same set-back does not occur as in the case of a plant where the bud has already burst ; in the latter case the bud shoot sometimes issues from the axil of the original bud which has experienced a set-back.

As regards planting out, the laterals and the taproot are trimmed and the stump sunk to the level of the base of the patch. Within a year from the time of budding when the budded branch may show about 9 inches and more of brown bark at the base, the handle of the stump is cut back to the top of the patch at an angle of 45° and waxed or cow-dunged ; the branch then calluses over the cut surface and develops into the budded tree.

The Early Stages of Growth.

In the first twelve months the uniform and very definite features of a clone come to the fore, distinguishing one clone from another. One clone may have long pointed leaves, another short and rounded ; the growth of one will be condensed and sturdy, allowing of little spacing between the whorls, while the growth of another will be spindly and the leaf whorls widely spaced.

Apart from foliar distinctions, clones exhibit marked differences as regards their habit of branching. Some branch early while others leave one with the impression of an immense stalk with a crown of leaves, the trees growing away without throwing out the usual lateral branches. This is not a desirable feature of growth ; to bring about the production of lateral branches leaf pruning is to be preferred to thumbnail pruning of the apical bud, which may lead to disastrous results. If the apical bud is removed, the laterals issue directly below the original apex, imposing a terrific strain on the tree, with the result that many of the branches break in the first gale of wind, etc.

Mention should be made of the characteristic development of " sucker-whorls " issuing from below the apical bud ; if these suckers are not removed a heavy whorled arrangement develops at maturity, resulting in an unnecessary breaking away of the branches, unless heavily pruned. In some cases the growth is diverted into these suckers, the apical bud being depressed at the base ; in one case the apical bud had been arrested at 3 feet from the ground, the suckers continuing to develop at the expense of the usual apical growth.

Considerations of the Mature Tree.

By this is understood a budded tree, 18-20" in girth at 3 ft. from the ground at 5 years old in the further East ; in this mature tree certain very prominent features are noticeable.

The Cylinder Habit.

The cylindrical habit of a budded tree, the girth at the issue of the first branches being nearly equal to that at the base, is one of the most striking features of budded rubber ; this is due to the fact that the internal factors which go to make such a tree differ very markedly from those of a tree grown direct from a seedling ; it is only a portion of a tree— a branch translated into the form of one.

The Club Foot.

At the base of many budded trees is a club foot development resembling the broad end of a piston rod ; at one time this was considered an undesirable feature, but is now no longer regarded in this light.

The Canopy.

This is generally very vigorous and very dense, eclipsing the vigour of the canopy of a tree from a seedling ; in some cases the canopies are so dense that they require considerable pruning and thinning at maturity.

The Heavy Seeding Habit.

It is a noteworthy feature that a budded tree seeds very heavily and is a more prolific seeder than rubber grown from seedlings. This habit has been

construed by some as a sign of weakness and a short life period ; such an interpretation is open to criticism. It may well be that the surplus food consequent on the more vigorous development of the canopy finds an outlet in the production of fruit, the remaining points of growth on the tree being unable to make use of it.

Again, such a heavy production of seed may be the outcome of increasing the number of points of the original branch on which seed can be produced.

The Canopy Development on Budded Trees.

As already pointed out, this is, in most cases, very different from that exhibited by a tree grown from a seedling. In many cases there are too many branches for the tree to carry ; if these are not thinned out, the clone will be liable to branch breakage ; it is unreasonable to expect any tree to support as many as four to five large branches issuing at the same level from the main stem ; if three out of the five are removed, the danger of branch breaking can to a great extent be obviated.

Many types of canopy could be enumerated, of which the following might be taken as examples :-

1. A very dense cone-shaped canopy with many branches and leaves.
2. A parachute type of canopy.
3. A straggling canopy with branches standing out irregularly.
4. A canopy with many whorls, with three to five branches arising from the same level.
5. The normal canopy ; a type which is a little difficult to distinguish from that exhibited by an average tree grown from a seedling.

The above and other types of canopy or crown development are to be found in budded rubber.

It must not be supposed that the growth habit is always all that is to be desired ; in some clones undesirable features are developed, such as cinked and twisted stems, the presence of large dormant buds in the form of wooden nodules, the development of nodules on the panel after tapping ; the first two features are not, however, confined to budded rubber.

The Bark of Budded Rubber.

If it was desired to be supercritical it might be said that this was the most unpleasant feature of all.

The bark of a budded tree is that of typical branch bark approximating to half the thickness of the bark of a normal stem ; the thickness taken over many trees was .75 to .85 cms. as opposed to 1.2 to 1.5 cms. for a normal tree.

In spite of the thin bark it is possible to tap a budded tree without wounding and obtain a satisfactory yield of latex. The laticiferous complement and the pattern is very different from that of a tree grown from a seedling.

The numbers of laticiferous cylinders for certain Avros clones given in the

Archief voor de Rubber Cultuur are 10, 12, 15, etc.; as is only natural, the number of laticiferous cylinders in a budded tree falls considerably short of that found in the parent tree.

For example, members of a proved clone from a Mother tree with 40 cylinders were found to possess only 12-15 rows of laticiferous tubes.

The stone cell distribution is, however, not as pronounced as in the average tree; this is to the advantage of budded rubber; it is sometimes claimed that the bark characteristics are those of the inner half of a normal bark sample, from which the greater part of the crop is derived.

As regards the bark renewals, these in the present state of our knowledge can be said to be satisfactory; in some cases the renewed bark is wavy and lumped; such features, however, are not uncommon in ordinary rubber when the tapping has gone over deep in a dry spell; fortunately, they cannot be said to be a constant feature of budded rubber.

It may be possible with an increase in the age of the bark that the present thin bark will fill out and approximate to that of the average tree; this remains to be determined.

By way of conclusion it can be said that there are no substantial scientific grounds for supposing that the bark renewal will not be satisfactory; there is no ground for considering that bark renewal is any more a function of the main stem than of a branch; it is governed principally by the supplies of organic material diffusing through the phloem to the growing points of the tree, which are interrupted and drawn upon by any tapped surface.

The Yields Obtained from Budded Trees.

Without attempting to furnish a panorama of figures it may be said that budded trees have been produced which have yielded 15 lb. of rubber per annum at 7 years old; certain of the proved Avros clones of the same age are yielding at the rate of 10 to 12 lb. per annum.

The yield of an average seedling for such ages may be taken as 2-3 lb. of rubber per annum.

One of the characteristic features of the yield from a budded plant is its uniformity. The yield from different individuals of one and the same clone is very uniform, the slight differences in yield being due to the more rapid growth rate of the individual determined in the main by factors operating in the stock.

A yield of +1,250 lb. of rubber per annum from a mature field of budded trees, at 10 to 15 years old, may probably be taken as a safe figure as compared to 450-500 lb. from ordinary unselected seed. It is not unlikely that the 1,250 lb. per acre mark will be exceeded.

Nevertheless, when planting up improved strains it is as well to plant one row of budded trees and one row of selected seed; it may be possible that a budded tree will develop undesirable features, though such likelihood is not very great in the case of carefully selected and proved material; the alternate

rows of selected seed, however, are an insurance against heavy losses should the views of the pessimists be subsequently substantiated.

It is considered convenient to plant 200 trees to the acre, 20 x 20 quincunx or 20 x 10 avenue; other distances can, of course, be employed. It is not altogether advisable, however, to go to the other extreme and plant about 300-400 trees to the acre, to secure a wide field of selection, as is sometimes advocated. The advocates of the 400 system with thinning out at the end of the third year may probably not have attached the same degree of significance as others to the fact that the value of a tree at 3 years old is very problematical and difficult to decide; many trees in an immature state giving a low yield at 3 years are often found at 5 years to be better trees than their neighbours.

Were it possible to delay test tapping to the end of the fifth year, when the value of a tree can be more accurately gauged, such a system would be excellent; but, unfortunately, the dense planting leads to the development of spindley trees more akin to telegraph poles than rubber.

The Field of Budded Rubber.

It is convenient to enter into a few considerations on related subjects.

Leaf Disease.

Leaf disease in rubber will be a menace for some time to come; it may be possible, by budding on to a proved clone at, say, 10 feet from the ground, the bud of a tree with a resistant crown, to produce a high yielding tree resistant to *Phytophthora* and *Oidium* which at present cause considerable damage. There is no reason to assume that the crown would break at the junction of the bud with the branch; the point of union is generally very firm. Were such an assumption correct, nearly every rubber tree raised from a stump in existence should have suffered long ago, the healing over process of the dormant bud issuing below the cut surface of a stump being similar to the healing over of a bud.

Foreign Stocks.

It may be possible by budding *Hevea Brasiliensis* on to stocks of *Hevea spruceana*, *collina*, etc., to produce a tree which can stand up to waterlogged conditions; the belief that these two latter species are not affected to the same extent by swampy soils as *H. brasiliensis* is not without its adherents.

Changes in the Laticiferous Complement.

It has been found that the stock may exercise a peculiar influence at times on the development of the laticiferous tissue in the scion or budded cylinder, leading to an unaccountable increase in the number of laticiferous cells. In the same way the scion has been observed to exercise a similar inexplicable influence on the stock. It may thus be possible by concentrating on certain

stocks to increase the laticiferous complement of the scion to the advantage of the budded tree.

DISCUSSION.

THE CHAIRMAN said those who were present at the meeting of the Society held on April 24th, 1907, might recall the discussion which took place after the very interesting address by Mr. Wright, Senior. Among other things, the possibility was then discussed of having to face the problem of disease in rubber. To-night it had been shown that the rubber industry had gone a great deal further than anyone who was present twenty-one years ago would have dared to hope at that time, because it had realised that the better policy was to take steps to protect the health of the trees rather than to run risks of incurring attack by pests and blight.

Many years before 1907 a fellow countryman of his, who had been engineer to a group of tea gardens, but had resigned his appointment and gone to Australia for a time, returned to India and finding no vacancy for an engineer, accepted the management of a tea garden. Knowing little about the subject, he got hold of what literature he could find, and amongst it a pamphlet written by a member of the Indian Medical Service, which laid special emphasis on the proper pruning of the plants. The engineer in question followed the advice there given and had successful results. The following season a neighbour who had seen what was done attempted to copy it, but his results did not come up to expectation. After the two had discussed the matter they agreed that the planter had been pruning with his hands, whereas the engineer had been trying to prune with his head. The author of the present paper, like the writer of the pamphlet on the pruning of tea, had made the how of his subject depend on the why, and had shown the extent to which success might depend on the capacity of those in the rubber industry to carry out the various operations required with the head as well as with the hands.

MR. HENRY N. RIDLEY, C.M.G., F.R.S., said the change in the methods of cultivation of rubber since it was first begun in 1889 and the trees first brought to bear in 1896 had been enormous. In the early days the planters thought that every scrap of ground must be as bare as a London pavement; not a blade of grass was to be seen. He had urged at that time, however, that the ground should not be bare as otherwise the trees would simply be washed out, and moreover, the roots stuck out of the ground and the coolies kicked pieces off them. He had grown a lot of rubber trees in grass before he got hold of leguminous weeds. Before he left, leguminous plants were being used and the difference was enormous, but it took a long time to get the idea into the heads of the planters.

Every possible form of tapping was tried in the Malay Peninsula. The Ceylon spiral was not approved of, as it was thought to injure the trees. Planting trees too close was another thing the planters were against, and absurd risks of disease were run. Finally, he put forward the slogan that whoever left dead boughs of rubber trees lying about a rubber estate was just as bad as a man who left a corpse in a slum. The people appreciated that and cleared up the dead wood. Attention was paid to fungus disease, but not much progress made with budding, which was a new invention. He never got from his rubber trees nearly as much rubber as was obtained at the present time; in fact, at first people were afraid to tap too severely.

With regard to future improvements, it was necessary to increase the amount of latex, which might be done by selection. He thought it would be a good idea

if someone were to go to the forests of Bolivia and get the plants they had there. Then there was cross-breeding, which was extremely important. The trees in his garden varied very much; one in particular produced two cups to the other's one, though there was nothing to show why that should be so. A great deal more had to be done in the way of manuring and to put down disease. Whenever a crop was being grown on a big scale disease increased. Leaf disease, about which everyone was alarmed at present, was no trouble in the early days, but had since changed its habits. Brown bast he never saw until after he left the Straits. Diseases would come once a crop was grown on a large scale, and it was essential to keep a regular check on the trees and to have a man watching for anything odd he saw on them.

No cultivation of an agricultural or tropical product had ever been dealt with in so scientific a way as rubber. The days for rule of thumb methods had passed; the cultivation of rubber was not a gardener's job, but a scientific one.

MR. ERIC MILLER appreciated the skill with which Mr. Wright had covered such a wide field. He believed the rubber industry was only now beginning to appreciate the value of scientific research. It had had the opportunity to take advantage of it all through its history, but the industry had grown at a very rapid rate and until recently had not paid enough attention to the scientific side of the cultivation of rubber. Until the slump which occurred in 1919-1920, with the consequent restriction of output afterwards, rubber trees were pushed to the utmost of their capacity without sufficient regard to the future. The slump had given the industry time to think, and it was taking serious stock of its present position and looking to the future.

He hoped the industry would realise that the work now being done in improving the strains of the trees was as yet in its infancy, and that it would not do to rush too fast into the adoption of this or that new type of rubber tree until more time had elapsed, and the scientists had had the opportunity of proving more definitely the value of the types that were being produced.

It was well known that rubber was a wonderful surface material for roads. A suitable means had at last been found for anchoring the rubber to the road surface, but it would be some time yet before surveyors were convinced that rubber roadways were a commercial proposition.

PROFESSOR CHARLES R. DARLING said he was not an expert on rubber, but wished to put a question regarding the chemical side of the matter so far as it related to soil. Some twenty years ago he asked a gentleman engaged in the rubber industry whether soil made any difference, and received the reply that it did not, because rubber would grow anywhere. He did not believe that, and now he had heard Mr. Wright mention good and bad soils. He would be grateful for some idea of what constituted the difference between a good soil and a bad soil. In one case that came under his notice he was asked to give an opinion whether a certain soil from the West Coast of Africa would be suitable for rubber. The particular feature of that soil was that it was entirely destitute of lime. It would be of interest to know whether lime was an essential constituent of soils for growing good rubber.

It was gratifying to see that active scientific research was going on in the rubber industry, because if this country was to retain that industry and remain pre-eminent in it, it could only be by continuous scientific research on the lines suggested in the paper.

MR. WALTER C. HANCOCK said that two aspects of the paper were encouraging. For those who had invested money in rubber, rubber prospects from the financial

point of view were greatly improved owing to the industry having been placed in a comparatively short time on a sound scientific basis. Secondly, it was satisfactory to know that avenues were being opened up for young men training in science and technology, for employment in the plantation industry as chemists, botanists, plant physicists and soil physicists.

MR. W. J. GALLAGHER said there had always been a good deal of scientific advice available, but in the early days of the industry it was not always possible to apply this, or to get people to accept it. From the earliest days, for instance, planters were alive to the importance of attending to disease. The plantation industry had now taken on the character of most other industries; it was a progressive industry. Every month saw something learnt, and with the larger body of people now engaged in the industry and the growing field of experience, the progress made became more striking as time went on.

There had been a dividing line in the progress of the rubber industry. The first fifteen years were more or less taken up with attempts to improve the quality of the product as put before the manufacturer. Then some people began to think that that had gone so far as it profitably could, and that the best thing to do was to try to increase the output per acre. That movement started about 1917, and could hardly have started earlier since it was bound up with other matters. Most of the experiments previous to 1917 or 1918 were not of much value, because the optimum size of a plot and the probable error had not been discovered. It was found that 30 per cent. of the trees gave 70 per cent. of the yield. That suggested that the low bearing trees should be got rid of, and if the optimum standard was taken at 80, all those trees should come in the 30 per cent class. The first improvement, therefore, was close planting—not 400 to the acre, as the lecturer had referred to, but something like 200.

The suggestion was then made of taking the yield of every tree, and that brought out striking differences in yields and suggested that good trees only should be employed in future. Owing to uncertainty as to how the rubber flowers were fertilised layering was tried, which was unsuccessful, then marcotting, but this also proved unsatisfactory. Budding was the last thing experimented with.

It would be seen, therefore, that the industry had been steadily progressing. The developments which had occurred could not have taken place much sooner than they did. The spirit of progress was, and had always been, a striking characteristic of the rubber industry.

He would like to emphasise what the lecturer had said with regard to draining. The water which fell on the soil in the form of rain should never run straight off it into a drain, whatever the nature of the land, and the only way to stop that on steep land, of over 1 in 10, was to terrace it. He believed in straight, clean-cut terraces. If the land was absolutely flat it was necessary to have drainage to take away the sub-soil water and so aerate the soil.

With regard to cover plants, he would like to point out that no cover plants would stop wash. The heavy sand was held up, but the light, rich silt went off the land, and if one went to look at the drains in the valley one would find them filling up rapidly. The test of soil conservation was the state of the drains in ravines.

MR. CHARLES HERBERT WRIGHT, in reply, said that with regard to imported strains of rubber from the Amazon, he did not think they were altogether necessary to improve the present strains of rubber, because on any estate there were high yielding trees. On some estates there were some exceptionally fine trees, and it

should be sufficient to utilise those. By introducing strains from the Amazon one might introduce unwittingly species which had a lot of resin in the latex and a smaller amount of rubber. If such trees were planted among ordinary *Hevea Brasiliensis* the fertilisation of the latter by the former might have an injurious effect on the rubber-producing qualities of the latex. Moreover, there was a serious leaf disease in the Amazon, and that would have to be guarded against.

Every year that a fungus lived on its host it became more educated as to the conditions of that host. A weak disease would become virulent in the course of years.

With regard to the prospects of budded rubber, he agreed that it was necessary to proceed with caution. There were many mistakes which could be made, and many of those mistakes were being made with the budded rubber planted to-day. There was not only the question of yield to be considered, but other characteristics; the branches of some trees broke easily; in some varieties there was a tendency to brown bast. Some of the trees he had seen, however, would repay planting on a large scale.

He did not think an analysis of the soil was of such value as the decision one could make by looking at the growth of the jungle on the soil before the rubber was established. Where there was a heavy growth of jungle it was usually possible to grow good rubber. The best soils for rubber varied in different countries; it was a matter of physical texture more than chemical value. There were some very hardy trees in Ceylon which grew among rocks. Not much work had been done on the effect of lime, but there was a deficiency of lime in most tropical soils. How far the application of lime to neutralise acidity was desirable for rubber he did not know.

Mr. Gallagher, who he was glad to see had joined in the discussion, was in charge of the H.A.P.M. plantations for a considerable time and was responsible for all that had been done there in regard to selected seed, budding, and the other important experimental work which was now being carried on in Malaya, Ceylon and other countries. Cover plants were a vexed point; some people held they would not hold the silt, and others that they would. The truth was that it depended on the density of the cover.

On the motion of the Chairman, a hearty vote of thanks was accorded to the lecturer for his paper, and the proceedings terminated.

GENERAL NOTES.

NORTH EAST COAST EXHIBITION OF INDUSTRY, SCIENCE AND ART.—The North East Coast Exhibition of Industry, Science, and Art will be held at Newcastle from May to October, 1929. The Exhibition, which is under the patronage of H.M. the King, with the Hon. Sir Charles Parsons, O.M., K.C.B., F.R.S., as President, will cover almost every branch of manufacture, while special sections will be devoted to Science and Art. An Art Gallery is being built for the reception of a fine collection of works of Art as well as Photography, and it is expected that the arrangements will include Conferences on various subjects, sporting events, tournaments and pageants.

A Prospectus containing the rules and regulations can be obtained on application from the General Manager, Exhibition Offices, Pearl Buildings, Northumberland Street, Newcastle-on-Tyne.

SEVENTH INTERNATIONAL CONGRESS OF PHOTOGRAPHY.—The Seventh International Congress of Photography will be held in London from July 9th to July 14th, 1928, under the auspices of the Royal Photographic Society and in co-operation with the Commission Permanente des Congrès Internationaux de Photographie.

The Congress is being organised by a Committee of representatives appointed by the leading Scientific and Photographic Societies of Great Britain at the invitation of the Royal Photographic Society. It will provide an opportunity for all who are interested in any branch of photography or its applications to meet together to discuss points of common interest, and to agree on standardisation of methods of procedure, apparatus and so on. Among the points for standardisation to be considered will be those relating to cinematography and plate-testing methods, which were dealt with in a preliminary manner at the previous Congress in Paris in 1925.

Further information, including a copy of the Regulations, can be obtained on application from the Secretary, Organising Committee, Royal Photographic Society, 35, Russell Square, London, W.C.1.

INTERNATIONAL HOUSING AND TOWN PLANNING CONGRESS.—An International Housing and Town Planning Congress will be held at Paris in the Palais de la Sorbonne from July 2nd to July 8th, 1928, under the auspices of the Municipal Council of Paris and the General Council of the Department of the Seine. The opening of the Congress will be attended by H.E. the President of the French Republic.

There will be papers and discussions on the following aspects of housing :—(1) Building costs ; (2) Rural housing ; (3) Housing of the very poor ; while in the sphere of Town Planning the following subjects will be dealt with :—(1) Mass and density of Buildings in relation to Open Spaces and Traffic Facilities ; (2) Legal and Practical Difficulties in carrying out Town and Regional Plans.

Further information, including a copy of the Provisional Programme of papers, social functions, and tours, etc., can be obtained on application from the Secretary, International Federation for Housing and Town Planning, 25, Bedford Row, London, W.C.1, or 29, Rue de Sévigné, Paris (3^e).

MEETINGS OF THE SOCIETY.

ORDINARY MEETINGS.

Wednesday evenings at 8 o'clock.

APRIL 18.—ALFRED C. BOSSOM, F.R.I.B.A., "American Architecture." PROFESSOR A. E. RICHARDSON, F.R.I.B.A., will preside.

APRIL 25—DR. J. M. RITCHIE, M.A., F.C.T.B. "The Education and Training of the Blind." CAPTAIN SIR BEACROFT TOWSE, V.C., K.C.V.O., C.B.E., Chairman of the National Institute for the Blind, will preside.

MAY 2.—WILLIAM TAYLOR, of Messrs Taylor, Taylor, and Hobson, "The Standardisation of Apparatus for Science Teaching."

MAY 9.—

MAY 16.—

INDIAN SECTION.

Friday afternoons, at 4.30 o'clock.

Date to be hereafter announced :—

SIR JAMES MACKENNA, C.I.E., "The Sugar Industry in India, Java, and Mauritius."

DOMINIONS AND COLONIES SECTION.

Tuesday afternoons at 4.30 o'clock.

MAY 22.—CAPTAIN SIR CECIL ARMITAGE, K.B.E., C.M.G., D.S.O., "Gambia" (illustrated by lantern slides).

DR. MANN LECTURES.

A. G. HUNTLEY, May Construction Company, Ltd., "Applied Architectural Acoustics." Three lectures. April 16, 23 and 30.

The syllabus was published in the *Journal* dated January 27th.

MEETINGS OF OTHER SOCIETIES
DURING THE ENSUING WEEK.

MONDAY, MARCH 26. Actuaries, Institute of, Staple Inn Hall, Holborn, W.C. 5 p.m. Messrs. T. F. Anderson and H. O'Brien, "Notes upon Experiments with Actuarial Functions and Fourier's Series."
Geographical Society, Lowther Lodge, Kensington Gore, S.W. 5 p.m. Prof. W. G. Fearnside and Mr. W. H. Wilcockson, "A Topographical Study of the Flood-swept Course of the Porth Llwyd above Delgarrog."
London Vegetarian Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 8 p.m.
Mechanical Engineers, Institution of, Storey's Gate, S.W. 6.30 p.m. Mr. R. E. L. Maunsell, "The Trend of Modern Steam-Locomotive Design."

TUESDAY, MARCH 27. Ancient Buildings, Society for the Protection of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 8 p.m.
Anthropological Institute, 52, Upper Bedford Place, W.C. 8.30 p.m. Sir Arthur Keith, "Human Remains discovered by Sir Aurel Stein in Ancient Cemeteries of the Taklamakan Desert."
Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. M. Sargant-Florence, "Colour and Co-ordination."
Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Prof. J. S. Huxley, "The Behaviour of Animals." (Lecture VI.)

WEDNESDAY, MARCH 28. Bankers, Institute of, at the School of Oriental Studies, Finsbury Circus, E.C. 5.30 p.m. Sir John Paget, Bt., "Recent Developments in Banking Law."
Civil Engineers, Institution of, Great George Street, S.W. 6.30 p.m. Mr. R. F. Legget, "The Limitation of Concrete as a Material in Construction."
Library Association and the Association of Special Libraries and Information Bureaux, at the London School of Economics, Houghton Street, Aldwych, W.C. 6.30 p.m. Discussion on Recommendations with respect to Special Libraries (contained in report of the Public Libraries Committee of Board of Education) opened by Mr. Arundell Esdaile and Sir Geoffrey Butler.
Naval Architects, Institution of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 11 a.m. Admiral of the Fleet the Right Hon. Lord Wester Wemyss, Presidential Address; Sir John H. Biles, "The Present Position of the Question of Fuel for Ships." 3 p.m. Mr. J. Foster King, "Bending and Loading of Ships."
North-East Coast Institution of Engineers and Ship-builders, Bolbec Hall, Newcastle-upon-Tyne. 7.15 p.m. Mr. J. C. Stewart, "Modern Mould Loft Practice."

THURSDAY, MARCH 29. Chemical Society, Burlington House, W. 8 p.m. (1) Messrs. A. H. Dickens, W. E. Hugh and G. A. R. Kon, "The Chemistry of the Three-carbon System. Part XVII. α -cyclohexyldeneacetone and -methyl ethyl ketone." (2) Messrs. F. Challenger and A. T. Peters, "The Nitration of Aromatic Thiocyanates and Selenocyanates." (3) Messrs. F. Ashworth and G. N. Burkhardt, "Effects induced by the Phenyl Group. Part I: The Addition of Polar Reagents to Styrene and the Behaviour of

the Halogenated Ethylbenzenes." (4) Messrs. E. B. R. Prideaux and C. B. Cox, "On Selenium Tetrafluoride." Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m.

Linnean Society, Burlington House, W. 5 p.m.
Naval Architects, Institution of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 11 a.m. Eng.-Capt. A. Turner, "A Note on Experimental Diesel Engines." 12 (noon). Mr. E. H. Mitchell, "Design and Propulsion of Fast Double-ended Screw Vessels." 3 p.m. Messrs. E. L. Champness and F. McAlister, "Further Notes on the Relative Strength of Fine and Full Cargo Vessels."
Mr. W. Sprague, "An Experimental Comparison of the Performance of Model Propellers working in Air and in Water."
8 p.m. Prof. Dr. E. G. Coker, "Stresses in the Hulls of Stranded Vessels." Mr. G. H. Hoffmann, "The Effertive 'I' of H.M.S. 'Wolf'."
Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Captain Martin Flack, "Physiological Aspects of Flying." (Lecture II.)

FRIDAY, MARCH 30. Architects and Surveyors, Incorporated Association of, Wilbraham Place, S.W. 7 p.m. Mr. W. M. Baird, "The Rise and Progress of Quantities and a Plea for a British Empire Mode of Measurement."
Chadwick Public Lecture, at 9, Conduit Street, W. 8.15 p.m. Dr. R. F. Stradling, "Baibus Built a Wall." (Bossm Gift Lecture.)
Geologists' Association, at University College, Gower Street, W.C. 7.30 p.m. (1) Mr. A. G. Davis, "Geology of the Clapham-Morden Railway Extension." (2) Mr. E. M. Venables, "The London Clay of Bognor." Miss Helen M. Muir-Wood, "A New Brachiopod, *Disciniscus Ferroviae*, from the Woolwich Beds."
Metals, Institute of, at the Applied Science Department, University of Sheffield. 7.30 p.m. Dr. W. H. Hatfield, "Non-Ferrous Metals in Relation to Ferrous Metallurgy."
Naval Architects, Institution of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 11 a.m. Lieut.-Col. V.C. Richmond, "Some Modern Developments in Rigid Airship Construction." Messrs. G. S. Baker and J. L. Kent, "Experiments on the Propulsion of a Single-Screw Ship Model." 3 p.m. Mr. W. G. A. Perring, "The Vortex Theory of Propellers and its Application to the Wake Conditions existing behind a Ship." Mr. John Tutin, "Cavitation." Mr. J. Lockwood Taylor, "Statistical Analysis of Voyage Abstracts."
Royal Institution, 21, Albemarle Street, W. 9 p.m. Sir Ernest Rutherford, "Radio-active Atoms and their Structure."
Transport, Institute of, at the Midland Hotel, Manchester. 6.30 p.m. Mr. J. L. Clewes, "Goods Transport by Road Motor: its Financial and Statistical Aspects and Limitations."
At Leeds, paper by Major Frank Bustard.

SATURDAY, MARCH 31. Royal Institution, 21, Albemarle Street, W. 3 p.m. Sir Ernest Rutherford, "The Transformation of Matter." (Lecture IV.)

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*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C.(2.)*

NOTICE.

SEVENTEENTH ORDINARY MEETING.

WEDNESDAY, MARCH 21st, 1928. COLONEL SIR HENRY LYONS, D.Sc., F.R.S.,
Director of the Science Museum, in the Chair.

A paper on "The Modern Typewriter and its Probable Future Development" was read by LIEUT.-COMMANDER RUPERT T. GOULD, R.N. (ret'd).

The paper and discussion will be published in the *Journal* dated June 1st.

PROCEEDINGS OF THE SOCIETY.

INDIAN SECTION.

SIR GEORGE BIRDWOOD MEMORIAL LECTURE.

FRIDAY, FEBRUARY 10th, 1928.

THE RIGHT HON. VISCOUNT CHELMSFORD, G.C.S.I., G.C.M.G., G.C.I.E., G.B.E.,
in the Chair.

THE CHAIRMAN, in introducing the lecturer, said that the Sir George Birdwood Memorial Lecture, instituted in memory of Sir George Birdwood, gave an opportunity of rescuing something from those hidden stores of knowledge which either died with the men who had accumulated them in the course of their service or lay buried in the voluminous reports of the Government of India. One often read in the papers of the death of someone who had done fine service in India and felt that so much knowledge had died with him, and that no record had been left by him of the knowledge he had accumulated during his years of service. In view

of the accumulating mass of literature in the archives of the Government of India, it could not but be regretted that something was not done to bring the pearls out of that accumulation to the knowledge of the general public. He had in mind something which was attempted during his own period as Viceroy. Many connected with India would remember the old Moral and Material Progress Report, that mass of statistics which used to be sent from India and put together in the India Office. During his term as Viceroy an endeavour was made to transform that into something presentable and readable, and he thought it could be claimed for the productions which had been put forward by those officers deputed to the task that, at all events, in place of that undigested mass of statistics they had produced something the public could read with interest and almost with pleasure.

To-night the Society was fortunate in its lecturer, because he was a man who could speak from both those sources. Sir Edward Gait was 36 years in India, and rose to the high position of Lieut.-Governor of Bihar and Orissa, while for five years he had been a member of the Secretary of State's Council. Personally, he could well remember the interest Sir Edward took in the antiquities of his Province. In addition, on two occasions Sir Edward had been that very mysterious person, the Commissioner for the Census of India. It would therefore be seen how well qualified Sir Edward was to deliver a lecture on a subject which would be very dear to the heart of Sir George Birdwood, in whose memory the lecture had been instituted.

The following lecture was then delivered:—

ANCIENT BIHAR AND ORISSA.

By SIR EDWARD A. GAIT, K.C.S.I., C.I.E.,

Formerly Lieutenant-Governor of Bihar and Orissa.

I need hardly say that I feel much honoured by the invitation to deliver this year's "Birdwood Memorial Lecture." As the Royal Society of Arts has allowed me to choose the subject, I have decided to speak about the Province of Bihar and Orissa, in which I served for many years.

In 1765 the Mughal Emperor Shah Alam granted to Clive the *diwani*, or financial administration, of Bengal, Bihar and Orissa. This great area was administered as a single unit until 1905, when the population exceeded 80 millions and it was recognised that some form of subdivision was unavoidable in the interests of good government. The Eastern part of Bengal proper was accordingly cut off and amalgamated with Assam. The partition of their country aroused the utmost discontent amongst the politically-minded Bengalis, and at the Delhi Durbar of December, 1911, a revised distribution of territory was announced by H.M. the King Emperor. Under the new arrangement Eastern Bengal was detached from Assam and reunited to Western Bengal, while Bihar, Chota Nagpur and Orissa were formed into a separate province with the designation "Bihar and Orissa."

Bengal thus became the most homogeneous province in India, consisting in the main of a level alluvial plain, in which Bengali is the language of almost the entire indigenous population. Bihar and Orissa on the other hand remains highly heterogeneous. Beyond their recent association under Muhammadan and British rule, its three sub-provinces have very little in common. Bihar, in the north, is a fertile inland plain with a population rising in some purely agricultural tracts to 1,000 persons to the square mile. Its climate and inhabitants resemble those of the United Provinces. Orissa is a narrow strip of alluvium hemmed in between the Bay of Bengal and the broken country forming the fringe of the Central Indian plateau. Its climate is damp and relaxing ; its inhabitants are of poor physique, and cultivation is in many parts precarious owing to its liability to floods and drought. Each of these sub-provinces has its own distinctive language and script. Between them lies a tract of hills and upland which is sometimes called the Chota Nagpur plateau. In addition to the sub-province of Chota Nagpur, it includes in the North a district of Bihar and in the South a hilly area which is administered as part of Orissa. It is in most parts sparsely populated, and not many years ago was covered with forest and difficult of access. The soil is not very fertile, but it is exceptionally rich in minerals, and its production of coal and iron is the greatest in India. It is the home of numerous aboriginal tribes, many of whom retain their primitive Animistic beliefs and still speak non-Aryan languages. Others, like their Hindu neighbours, speak Aryan languages—Bihari in the North, Bengali in the East, and Oriya in the South.

It would be impossible in the course of a short lecture to deal with all aspects of such a diversified province, which has an area nearly as great as that of the British Isles and a population equal to that of England and Wales. So I propose this afternoon to confine myself to an outline of what is known regarding the remote past of each of the three sub-provinces. I have selected this branch of my subject, partly because it is one which would have appealed specially to Sir George Birdwood, and partly because a great deal of fresh light has been thrown upon it by the Bihar and Orissa Research Society, which was founded soon after the Province came into existence and has proved itself a very active and efficient body.

For centuries before the Christian era India had a copious literature embracing such subjects as religion, philosophy, logic and grammar. There were great dramatists and epic poets, but no real historians, though dubious dynastic lists are to be found in certain religious books. Less than ninety years ago, when Elphinstone wrote his great pioneer history of India, he found no material for a connected account of events prior to the advent of the Muhammadans. Since his time, however, a mass of information has been, and is still being, collected from many different sources. The most valuable are ancient inscriptions on rocks, pillars, buildings, images and coins and copper-plate title deeds of land grants. The earlier of these inscriptions are written in

archaic characters, the decipherment of which is due mainly to the genius of James Prinsep, who was, like Elphinstone, a servant of the East India Company. The amount of historical information now available varies greatly in different parts of India.

CHOTA NAGPUR.

It is practically non-existent in the case of Chota Nagpur. On the other hand, this sub-province is exceptionally rich in prehistoric antiquities. It is the only tract in Northern India where palæolithic implements have been found. Neoliths are very common. A cave near Singanpur, near the Western border



Ganesh Gumplia (cave) at Udayagiri.

of the Gangpur State, contains paintings of hunting and other scenes reminiscent of those made by Aurignacian man in the limestone caves of South-west Europe. Copper axe-heads have been found in many places, in some cases in an unfinished state, indicating local manufacture. One find consisted of a number of copper bars shaped like ploughshares. It is curious that whereas in Europe the earliest known metal tools are made of bronze, in India they are made of copper: the difference may be due to the rarity of tin in India. Copper and bronze ornaments and utensils of a later date and phallic emblems in stone or terra cotta are frequently dug up; and in some places finely finished and

bored beads of crystal, cornelian and other stones are often picked up after rain. Coins of the Kushan kings have been found. There are numerous remains of stone temples and sculptures and also of buildings made of bricks like those in use in Bihar more than 2,000 years ago. There are extensive burial grounds where massive sepulchral stones cover groups of earthenware jars. These jars contain calcined human bones, together with earthenware lamps and other vessels, and also copper and bronze bracelets, rings and other ornaments, crystal beads, etc. There are remains of ancient copper mines. Near one of them several hundred copper coins were recently found. They are a very rude imitation of the coinage of Kanishka, and had evidently been cast in moulds. Many of them were in an unfinished state, so that the place where they were found was probably a mint. The form of the letters on them suggests that they date from about the seventh century of our era.

These various relics show that the old idea that the present aboriginal inhabitants of the Chota Nagpur plateau have always been its principal occupants is no longer tenable, and that they must have been preceded, in some parts at least, by a more civilised race. In Ranchi there are widespread traditions of its former habitation by an ancient people called Asurs, to whom the present inhabitants attribute the burial places and ruins which I have just described. They are reputed to have been a tall and powerful race. It is impossible to say if they were identical with the Asuras of Vedic literature, but the facts that the latter were also worshippers of the Phallus and are said to have been expert in the working of copper suggest the possibility of some connection. Rai Bahadur S. C. Roy finds some remarkable resemblances between the Asur sites in Chota Nagpur and the finds they yield and the ancient ruins of Harappa and Mahen-jo-Duro in the Indus valley, of which we are still anxiously awaiting a detailed account. According to another recent writer, the earliest known rulers of South Bihar were Vedic Asuras, and if so, they would naturally have spread thence into Chota Nagpur. Whether these ancient people were exterminated or absorbed by the newcomers, or were driven to other parts of India, is a riddle that cannot now, and perhaps never will be, solved.

That aboriginal tribes are prone to migration is shown by the eastward drift of the Santals within living memory, and by the fact that Oraons now inhabit villages where Mundas once lived. Similar movements may have been in progress from time immemorial. Unfortunately there is little or nothing to show their extent or direction. Some tribes, notably the Oraons, speak dialects of the Dravidian linguistic family, which are more nearly related to the Tamil and Kanarese languages of the extreme South of India than to the nearer Telugu. The Dravidian family has no known affinities with any languages spoken outside India. Other tribes, including the Mundas, Santals, and Hos, speak dialects of the Austric family, the most widely

diffused linguistic family in the world. It is spoken in many parts of South-east Asia and in islands of the Indian and Pacific Oceans as far as Easter Island off the coast of South America. The only other surviving members of it in India are Khasi in Assam and Mon and Talaing in Burma ; but there are indications that cognate dialects were current over the greater part of the Gangetic plain before the advent of the hordes who brought the Aryan languages to India. The practice of erecting monoliths in memory of the dead, common amongst the Khasis and other more easterly tribes, prevails amongst the Mundas but not amongst the Oraons. These facts are suggestive, but it would be rash to assert that they afford any definite guide to their prehistoric migrations. Risley held, on the basis of head measurements taken by subordinates under his instructions, that whatever may once have been the case, there is now no physical distinction between the two groups of tribes. It is doubtful, however, whether the measurements in question were sufficiently accurate to be conclusive. Some competent observers consider that there is, in fact, a clear difference of type. A recent writer says :—" To one who has lived in a Mongolian country as I have, the semi-Mongolian appearance of the Hos is very striking." The traditions of the people themselves give us no help. In this connexion I may quote an experience of my own which shows how cautious one must be nowadays in placing any reliance on so-called traditions. When questioning some Hos on the subject of their past migrations, two intelligent headmen told me that their forbears had come from the North across snowy ranges. Their statements seemed to afford striking support to the late Colonel Dalton's views on the subject, but fortunately I happened to ask them whence they had obtained their information. Their answer was that they had learned it in their village school. Colonel Dalton's views had evidently found their way into the school " First Reader."

ORISSA.

Orissa is noted for its great temples which were constructed in early mediæval times. The most remarkable are the Saiva temples at Bhubaneswar, in number about one hundred, the so-called Black Pagoda, or Sun temple, at Konarak, and the Vaishnava temple of Jagannath at Puri. The last mentioned is famous for its car festival, when wooden effigies of the God Jagannath and his brother and sister are dragged by many thousands of excited pilgrims from the temple to the garden house in huge wooden cars. That of Jagannath himself is 45 ft. high and 35 ft. square and is supported on sixteen large wooden wheels. Many prostrate themselves in front of the car, and in former days, when less care was taken, accidents sometimes happened. These gave rise to the widespread but unfounded belief that self-immolation was a recognised practice at this festival.

The Orissa temples consist usually of a suite of four connected buildings in line. They disclose the evolution of what Ferguson called "one of the most complete and interesting styles of Indian architecture." Their special features

are the profuse and minute ornamentation, the grandeur of the general plan and the gigantic size of the stones and iron beams used in their construction. The coping stone of the Sun Temple at Konarak is twenty-five feet thick, and is estimated to weigh 2,000 tons, while one of its iron beams is about 23' long and 10" square.

Of still greater interest are the caves—sixty-six in number—with which the hills of Udayagiri and Khandagiri are honeycombed. These caves, which are 2,000 years old and upwards, range from natural caverns slightly



Lingaraj temple at Bhubaneswar.

improved by man, which served as the abode of Jain ascetics, to very elaborate and highly-decorated mansions. The most remarkable is that known as the *Rani-gumpha*, or Queen's Palace, which has sixteen rooms arranged on two stories. In front of it are long verandahs with figures of men and animals carved in high relief. There are numerous sculptured friezes. One of them is 60 ft. long; the bas-reliefs run in nine panels and appear to represent a connected story.

But with all this wealth of archæological remains, indicating an advanced state of civilisation, there is a remarkable dearth of historical information.

Orissa has a very extensive literature, and it is estimated that in Puri alone there are still over 200,000 palm leaf manuscripts. An examination of these manuscripts is in progress, but so far not one of a historical character has been found. The thirteenth edict of Asoka describes how that great Emperor conquered Orissa about 261 B.C., killing 100,000 in battle, while many times that number were deported or perished in consequence of the devastation caused by his army. But apart from this account of a terrible disaster, there is only one record containing detailed information regarding events in ancient Orissa. This is an inscription on a rock in the *Hathigumpha*, or elephant cave, at Udayagiri. It was first noticed in 1825. An eye-copy was made by Prinsep in 1837, but no workable reading was put forward until half a century later. This held the field until 1917, when after careful local inspection and the taking of a number of impressions Mr. K. P. Jayaswal—a most able and ingenious member of the Bihar and Orissa Research Society—published a reading of almost the whole of the inscription, which he has again recently revised in the light of further squeezes of doubtful letters and the comments made by other epigraphists on his original rendering. The inscription in question was incised under the orders of a king named Kharavela, who, according to Jayaswal ascended the throne about 183 B.C., and contains a detailed account of the occurrences in each of the first thirteen very eventful years of his reign. Though no mention even of his name is to be found in extant Hindu literature, this king was a great and powerful ruler. He ruled over a country called Kalinga, which included the northern part of Madras and the southern part of Orissa. He carried his victorious arms westwards to Berar and northwards across the Ganges. He twice invaded Bihar and on the second occasion brought back much valuable booty, including the image of a Jain saint which had been carried off from Orissa by the Bihar King Nandavardhana about 300 years previously. Kharavela executed numerous public works, including a palace, temples, forts and the cave dwelling known as the Queen's Palace which I have already mentioned. He repaired certain old irrigation tanks and extended a canal which had been constructed (*pace* Jayaswal) in the 4th century B.C. This shows that irrigation in Orissa dates from very ancient times. Kharavela carried on an extensive sea-borne trade and imported elephants from the south of India in specially made ships. He was a devout Jain, but also performed Vedic ceremonies and made valuable gifts to Brahma. He was a patron of music and other arts. He led out in procession the wooden statue of a king who had ruled the country 1,300 years previously. That King's name was Ketu, and it is interesting to note that in the *Mahābhārata* Ketuman is given as the name of the son and Commander-in-Chief of the King of Kalinga, who was killed by Bhim in the great battle of Kurukshetra. According to the dubious chronology of the Puranas, this battle took place about 1424 B.C., or about half a century after the date of Ketu, according to the round figure given in this inscription.

Kharavela's capital was at Tosali, now called Dhauli. This place had previously been the headquarters of Asoka's local governor, and that Emperor's famous edicts are still to be seen carved on a rock there. No vestiges of this ancient city have yet been found, except a silted-up tank and canal, the remains of a bridge over the canal, and heaps of bricks, potsherds and stone foundations.

After this brief illumination, we know practically nothing of the progress of events in Orissa until late mediæval times. It is one of the strangest anomalies in the whole course of history that we should have this full account, year by year, of the events of less than half a generation in the second century B.C., and scarcely another scrap of information for over a millennium. Considering how much lost history has been recovered elsewhere, we may hope that the discovery of forgotten manuscripts and inscriptions of various kinds, together with excavations at Dhauli and elsewhere, similar to those which have been so fruitful at other ancient sites in India, will yet enable some part at least of the lost history of Orissa to be revealed.

BIHAR.—THE SISUNAGA DYNASTY.

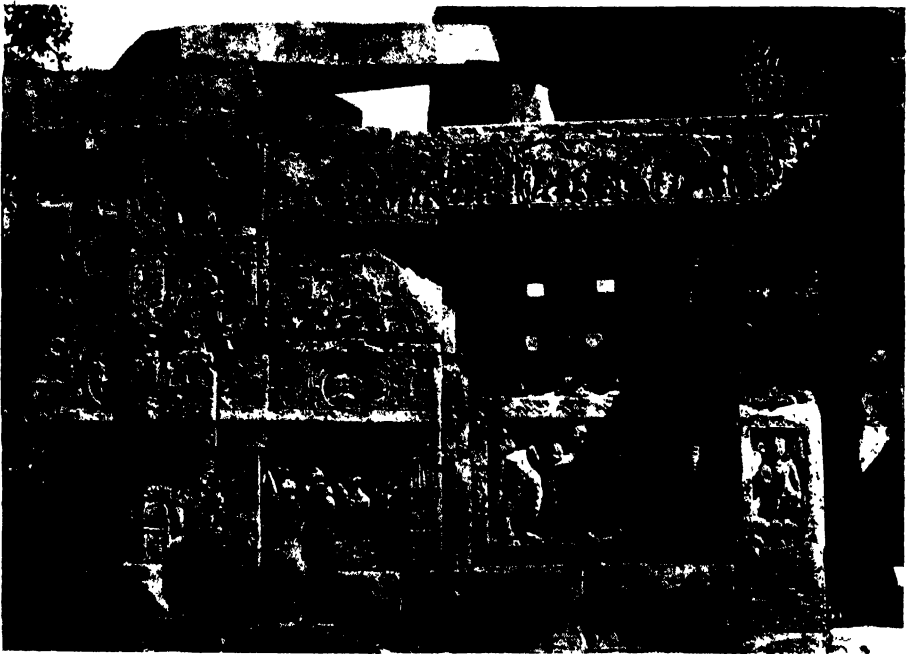
From an historical point of view Bihar presents a complete contrast to Chota Nagpur and Orissa ; we know more of its ancient history than of that of any other part of India. Though far earlier kings are named in Hindu literature, the first dynasty which can claim historical reality is that founded in Magadha, or South Bihar, by Sisunaga about the seventh century B.C. This king's capital was at Rajgir, in the south of the Patna district, the traditional capital of Jarasandha, one of the heroes of the *Mahabharata*. Apart from the quite recent discoveries at two sites in the Indus valley, the ruins of this ancient city are the earliest structural remains yet found in India. The outer walls are about $17\frac{1}{2}$ feet thick and are faced on both sides with massive undressed stones carefully fitted together without the use of mortar. During the reign of Bimbisara, the fifth king of this line, Gautama Buddha proclaimed the religion which, though it has disappeared as a recognised creed from the land of its birth, is still the faith of 500 millions of people in other parts of Asia. Buddha obtained enlightenment at Gaya, but he had commenced his studies at Rajgir, and he afterwards often preached and taught there. The first Buddhist Council to fix the tenets of the faith was held there after his death. Another great religion, that of the Jains, was founded about the same time by Mahavira, the son of a nobleman of Vaisali, north of the Ganges, and a near relative of one of Bimbisara's three queens. Thus Bihar was the birthplace of the two greatest Indian religions which intervened between the cult of the Vedas and modern Hinduism.

Ajatasatru, the next king of this dynasty, who was a contemporary of Darius of Persia, extended his rule over the whole of Bihar. He constructed a new capital about a mile from the old one at Rajgir. He also built a fort at

Pataliputra, where Patna now stands. Buddha is said to have visited that place in the course of his last journey to Kapilavastu and to have predicted that it would soon grow to be the greatest city in the world. Ajatasatru's grandson, Udayin, made Pataliputra his capital about 485 B.C.*

THE MAURYAS.

The next great King of Bihar was Chandragupta Maurya. He took a leading part in ejecting the Macedonian garrisons from northern India after the death of Alexander, and then, after making conquests rivalling those of Napoleon, became the first historical paramount sovereign of the greater part of India.



Some details of decorations on a temple at Bhubanesvar.

He defeated and drove away Seleukos, a general of Alexander, who, having made himself lord of Western Asia, endeavoured to emulate that great conqueror's exploits in India. When peace was made Seleukos sent Megasthenes as his ambassador to Pataliputra, and the fragments of his writings which have come down to us give a very full account of that city, in which he lived for many years. It was, he tells us, surrounded by a massive timber palisade with numerous towers and a deep moat. The royal palace excelled that of Darius in magnificence and contained a profusion of gold and copper vessels and richly-

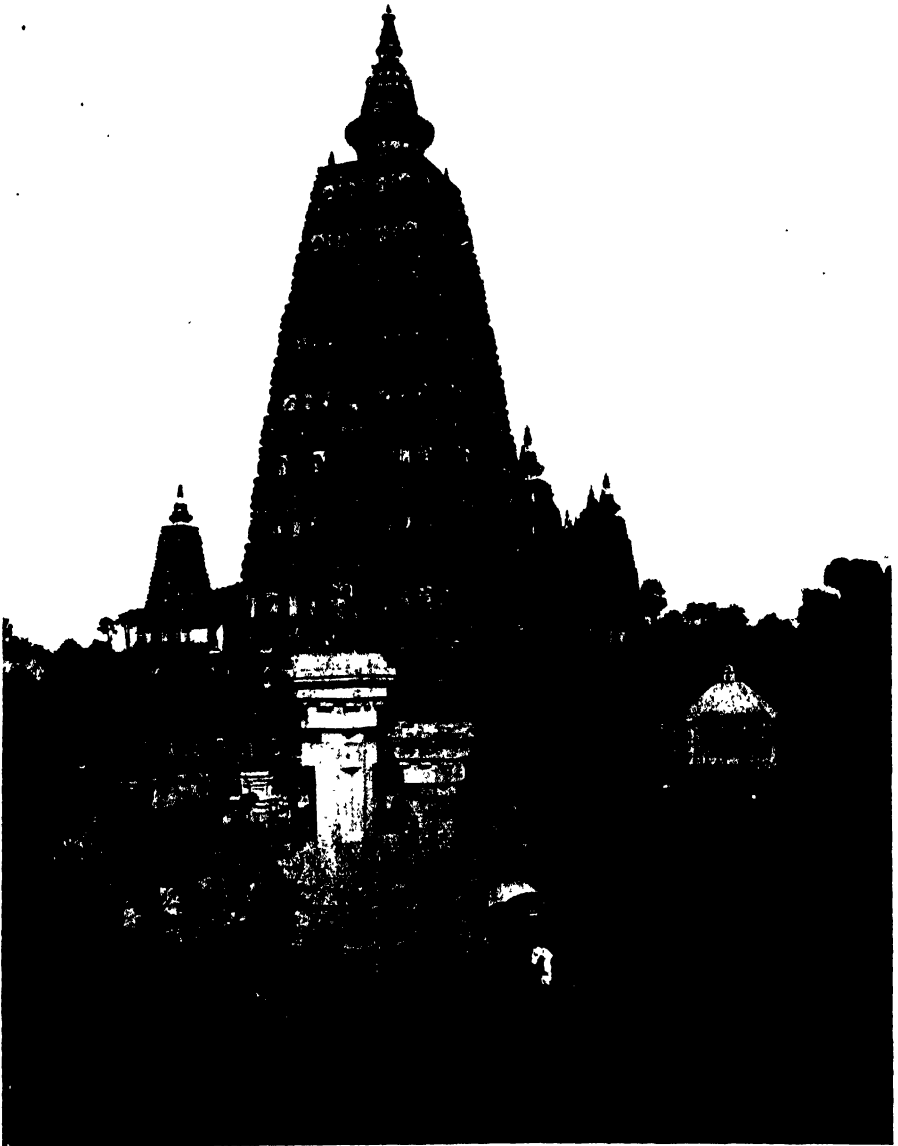
*This date, which is linked up with that of Buddha's death, is still a matter of controversy.

carved chairs and tables. The king travelled in a golden palanquin or on an elephant with golden trappings. He also rode on horseback. His principal amusement was the chase. He had a huge standing army and an Amazonian body guard. The system of administration was as elaborate and efficient as that of the Mughal Emperors. Outlying provinces were administered by Vice-roys. As in Mughal times a vigilant eye was kept on them by means of news writers, who submitted periodic reports to the Emperor. Regular censuses were taken and the registration of births and deaths was compulsory. The municipal administration of Pataliputra vested in a Board of thirty members.

Chandragupta's chief minister was a Brahman named Kautilya who wrote a famous book on the art of government. This was freely quoted by many subsequent writers, but the book itself had been lost sight of until a few years ago when a manuscript was found in Mysore which is believed by most authorities to be Kautilya's original work, though some think it to be a later recension of it. This book, like that of Megasthenes, throws a flood of light on conditions as they existed in India more than twenty-two centuries ago. It appears to have been based largely on similar works by previous writers, so that the subject was by no means a new one in India even at that distant date. In it war is regarded as inevitable, the stronger king always preying on the weaker. The usual form of government was an absolute monarchy, and, as in Mughal times, the king was always suspicious of his sons. He was assisted by a Council of Ministers. Eighteen departments of state are enumerated, including a Chief Collector of Taxes, an Accountant General and a Superintendent of Agriculture. It was the duty of the last-mentioned officer to assess cultivated land at rates varying according to the nature of the irrigation, which even then was regarded as a matter of such importance that a special department was maintained to deal with it. There were elaborate arrangements for colonizing waste lands. The King's nominal share of the gross produce was one-fourth, but it was swollen to about one-half, by irrigation and other dues. Salt was a Government monopoly, and there were taxes on imports, on sales and on wines and other liquors, as well as special levies, or *ahwab* as they are now called. There was an elaborate system of espionage, torture was a recognised means of obtaining confessions, and punishments were of Draconian severity. The seditious were to be got rid of quietly by means of secret assassins. When this book was written it was a crime to entertain Buddhist mendicants.

Pataliputra was not only the first historical capital of an Indian Empire. It was also a great centre of intellectual activity; in fact, the greatest in India after the fall of Taxila. The famous grammarian, Panini, made his home there, and it was there that the first collection of Jain scriptures was made. Quinquennial assemblies for the award of merit were held by Chandragupta and his successors. There was an advanced school of medicine, and it has been said that vivisection was first practised by its doctors. Sculpture flourished and many of the finest specimens in the Calcutta Museum were taken thither from

Bihar, often, alas, in early days, without any adequate record of their provenance. There is time only to mention one group of statues. In 1917, owing to erosion of the river bank at Didarganj, near Patna, a piece of stone became visible. On scraping away the earth, the finder discovered that it was the pedestal of a beautiful polished statue of a female cut out of a single piece of Chunār limestone, and sculptured entirely in the round. The proposal to call this the statue of a Yakshini, on the analogy of General Cunningham's description of two similar statues found at Patna about a century ago and now in the Calcutta Museum, led Mr. Jayaswal, who was sceptical as to this identification, to make a careful examination of the latter and of the inscriptions on the back of them. According to his reading of these inscriptions they represent, not Yakshas, but two kings of the Sisunaga dynasty—Udayin, who made Pataliputra his capital, and his son Nandavardhana. Several competent epigraphists confirmed his reading; and it therefore seemed obviously right that the statues should be brought back from Calcutta and erected in the city where these kings held sway twenty-four centuries ago. I approached Lord Chelmsford, the Viceroy, who was very sympathetic. So also was Lord Ronaldshay, the Governor of Bengal. But it was then found that other epigraphists disputed the readings, and it was impossible to say that Jayaswal's identification had gained universal acceptance. So, for the present, at any rate, Patna has had to content itself with plaster casts of these statues. In the course of the controversy a similar statue in the Muttra Museum, also of Chunar sandstone, was examined by Mr. Jayaswal, and his rendering of the inscription showed it to represent Ajatasatru, the father of Udayin. I am not aware if his reading of this inscription has been questioned. Whatever may be the ultimate conclusion, it may be noted that the commemoration of famous persons by means of statues was well known in ancient India. Bhasa, who flourished before the Christian era, tells of a gallery in which the statues of former kings were kept, while in Kharavela's inscription mention is made of the wooden statue of a king who ruled more than a millennium before Udayin. Hiuen Tsang speaks of a statue of the great grammarian, Panini, who was a contemporary of Ajatasatru. To many of us the statues in question appear clearly to be representations of actual persons, and the drapery on them is precisely what is described in ancient writings as suitable for residents in Magadha. On the other hand, Sir John Marshall attributes these statues to the time of Asoka. He recognizes the disparity between what he calls their more primitive workmanship and the skilful chiselling and brilliant polish of other monuments which are known to have been executed during Asoka's reign, but explains it on the hypothesis that the statues in question were carved by local artisans and the other monuments by craftsmen imported from Persia. I venture to suggest that it is at least equally likely that the more "primitive" works were, in fact, executed at an earlier period. The late Dr. Vincent Smith considered that they were executed not later than 400 B.C. If so, the art of sculpture in stone was already well matured in India twenty-three centuries ago.



Temple of Bodh Gaya.

Chandragupta's grandson was the great Asoka. He added the east coast to his ancestral dominions, and is said to have founded Srinagar, the capital of Kashmir. He erected a masonry wall round Pataliputra and built a palace of stone there. But he is chiefly famous as the great protagonist of Buddhism.

As everyone knows, he caused a series of edicts containing the cardinal points in the Buddhist creed to be inscribed on rocks and pillars in all parts of India, and sent out from Pataliputra missionaries to preach the faith far and wide, even in Egypt and Greece. Under his ægis the third Buddhist Council was held in Pataliputra.

THE SUNGAS.

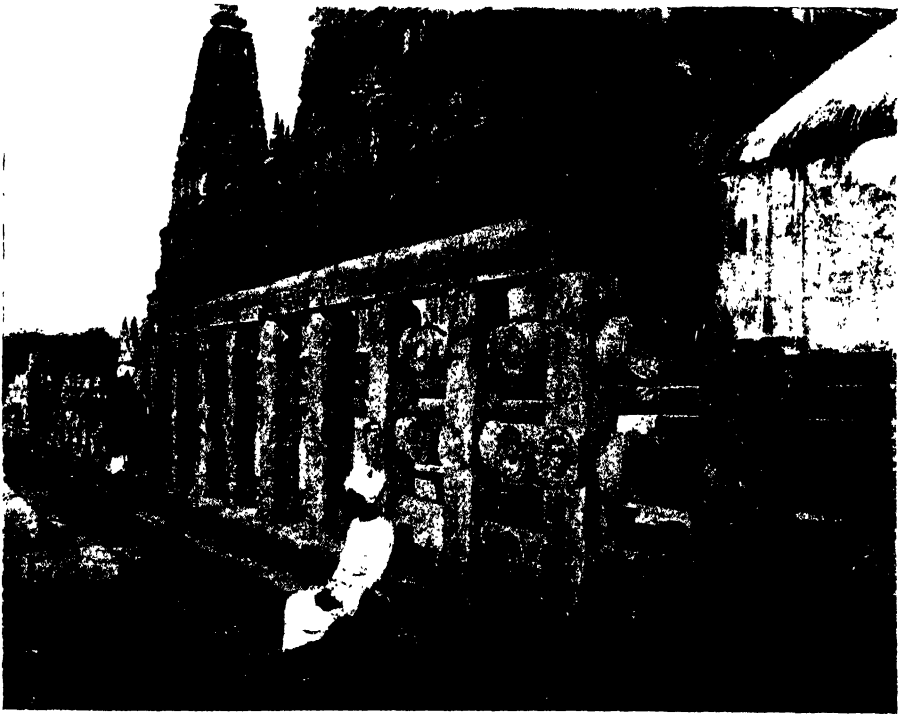
Asoka died in 232 B.C. Half a century later the last king of his line was assassinated by his commander-in-chief, Pushyamitra, who founded the Sunga dynasty. This King was a Brahman by caste. He inaugurated a revival of Hinduism and persecuted the Buddhists. He suffered defeat, as already narrated, at the hands of Kharavela, but on the other hand he defeated and drove out of India the leader of the last Greek attempt to conquer that country. After his death the empire gradually fell to pieces and the political centre of gravity moved to the West.

THE GUPTAS.

Some 500 years later, another Chandra Gupta, the founder of the Gupta dynasty, by his marriage with a princess of the Lichchhavis, who ruled north of the Ganges, gained a paramount position in Bihar, and brought a large part of what is now the United Provinces under his sway. His son, Samudra Gupta, though he was one of India's greatest monarchs, is not even named in Hindu literature, and we owe the full knowledge of his reign which we now possess solely to modern research—to the study of inscriptions on coins, copper plates and buildings, and on a pillar at Allahabad, which was already incised with the edicts of Asoka. The inscription on that pillar was made under his personal instructions, and, like the Hathigumpha inscription of the Orissa King Kharavela and the Behistun inscription of Darius, contains a very full account of the events of his long reign. He was a mighty conqueror and brought under his sway the whole of India north of the Narbada from the Brahmaputra on the east to the Jumna and Chambal on the west. He created, in fact, the greatest empire known in India since the days of Asoka, and Pataliputra became once more a great Imperial capital. According to his panegyrist, he excelled also in the arts of peace and was an accomplished poet and musician. He had relations with various foreign powers and received a mission bringing valuable gems from the King of Ceylon, who sought and obtained his permission to build a great monastery at Bodh Gaya. When Hiuen Tsang visited India in the 7th century A.D., this building accommodated 1,000 monks and many pilgrims from Ceylon.

A still greater monastery was that at Nalanda, which was for long the most celebrated seat of Buddhist learning in the world. Hiuen Tsang tells us that in his time it was the home of 10,000 monks who spent their lives in the pursuit of wisdom. No one was allowed to enter it until he had been severely catechized.

by the keeper of the gate, and the majority of candidates had to retire disappointed. Hiuen Tsang describes it as the most remarkable monastery in India for height and grandeur. He says it was constructed soon after the death of Buddha. Recent excavations at Nalanda show that the buildings there had several times fallen into ruins and that new ones had been constructed successively on the top of the old. No remains yet discovered can lay claim to a higher antiquity than the sixth century, A.D., but the legendary association of the site with the person of the Buddha encourages the hope that earlier finds will yet be forthcoming. Nalanda was finally destroyed about 1197, A.D., when Muhammad Bakhtiyar, Ghilji, captured the fortress of Bihar and slew all the monks, and so put an end to Buddhism in the land of its birth.



Stone railing outside Bodh Gaya Temple.

Samudra's son, Chandra Gupta Vikramaditya, added Malwa, Gujarat and Kathiawar to the Imperial dominions. The Chinese pilgrim, Fa Hien, visited Pataliputra during his reign and spent three years there pursuing his Sanskrit studies. He was so impressed by the grandeur of Asoka's palace that he ascribed its erection to spirits who at Asoka's bidding "piled up the stones, reared the walls and gates and executed the carving and inlaid sculpture in a

way that no human hands can accomplish." Charitable institutions were numerous and the capital possessed an excellent hospital where the poor were treated for all kinds of diseases. The country was peaceful and well governed, and crime was very rare.

The imperial power of the Guptas was broken by the Huns about 465 A.D., but they lingered on for several centuries as local rulers of Magadha under foreign overlords, such as Harsha Vardhana of Thanesar. Though the Guptas were Hindus, they tolerated Buddhism, and more than one of them erected noble buildings at Nalanda. But deprived of the prestige attaching to a State religion, Buddhism lost its hold over the masses, to whom the pomp and polytheism of the older religion had always perhaps offered greater attractions. This probably explains the sudden and complete extinction of Buddhism when Muhammad Bakhtiyar destroyed the monasteries and put the monks to the sword. The Gupta period was one of great intellectual activity in many different fields. The earliest of the religious books known as Puranas probably took final shape at the beginning of this period, and also, perhaps, the Code of law attributed to Manu, though some think that this work was compiled in the days of the Sunga dynasty. Mathematics and astrology flourished. So did the arts of music, painting and sculpture. Kalidasa, the renowned author of the *Raghuvansa*, *Sakuntala* and other poems, was the greatest poet, but there were many others who would have attained the highest distinction had they not been overshadowed by that great genius.

THE END OF PATALIPUTRA.

The downfall of the Guptas signaled the end of Bihar as the nucleus of a great empire. Henceforth it was fated to take a subordinate place in Indian history. Its ancient capital shared the same fate. Pataliputra was deserted and in ruins when Hiuen Tsang visited it. It may have been sacked by the Huns, or by Sasanka, the King of Central Bengal, who destroyed many Bihar monasteries and drove away the monks. It enjoyed a temporary revival in the eighth century, when the Bengal King, Dharmapala, after conquering Bihar, transferred his capital thither, but after that it fell into utter oblivion. Even the ruins were hidden by new soil formation and the efforts made in the course of the first archaeological survey to find the site failed so completely that it was concluded that it must have been washed away by the Ganges. In 1892, however, Colonel Waddell proved that this was not the case, and that the ancient city lay buried fifteen to twenty feet beneath the surface of the south part of modern Patna. He found various Maurya remains, and claimed, on the basis of Hiuen Tsang's description, to have located the position of many of the old buildings. It is difficult now to assign any reason why this comparatively low site should have been chosen for the capital in preference to the higher ground on the bank of the river, but there is no doubt that Waddell was right. Excavations made fifteen years ago by the late Dr. Spooner on the site

which Waddell had indicated as that of the King's palace brought to light the remains of a great hall. Spooner held this to be part of Asoka's palace, and pointed out that it appeared to have been modelled on the plan of the palace of Darius at Persepolis. The roof of the main portion was supported on eight, or perhaps ten, parallel rows of highly-polished stone pillars, running from north to south. The pillars were 20" in diameter and 20 ft. high. There were ten pillars in each row, and they were 15ft. apart. They had apparently stood on timber frames and supported a very massive wooden superstructure. South of the pillars was a series of wooden platforms, each 30 ft. long (from north to south), 5' 4" wide and 4' 6" deep. The state of the remains led Spooner to think that the building had suffered from two catastrophes, first a flood which deposited a layer of silt 9 ft. thick over the surface, leaving the building otherwise intact and still habitable, and then, several centuries later, a fire which completely consumed the masses of woodwork. One pillar which seems to have fallen during the flood was found lying on its side almost intact; the others had all disappeared. When the fire came they were apparently held upright by the silt and afterwards, when the wood beneath them rotted, sank gradually in the water-logged sub-soil. Their downward track is indicated by circular funnels filled with wood ashes together with broken fragments of the tops of the pillars which split off when the heat of the fire expanded the metal bolts inserted in them to fix the woodwork. Bearing in mind the fact that events which have actually occurred often appear in Indian religious writings in the form of prophecies, Spooner's theory of a flood and a fire may be regarded as receiving confirmation from the statement attributed to Buddha, that he foresaw three sources of danger to Pataliputra—fire, water and internal dissension.

On a higher level, above the ashes left by the fire, Spooner found ruined buildings of the Gupta period, which in their turn had been buried under fresh deposits of earth. A few furlongs away he traced for a distance of 350 feet the remains of the old timber wall. It consisted of massive wooden beams placed vertically and socketed to horizontal crossbeams. At both sites numerous remains were found of the Maurya and later periods, including some extraordinarily interesting terra cotta figurines.

ANGA, VIDEHA AND MITHILA.

Though, in the time available, I have been able only to deal with the kingdom of Magadha, there were several other ancient kingdoms within the confines of modern Bihar. One of these, known as Anga, corresponded to the districts of Bhagalpur and Monghyr, and had its capital at Champa. There was a still older and more famous one in Tirhut, or the Muzaffarpur division. This was Videha, the country of the Lichchhavis, who hold a very prominent place in Buddhist legends and who gave queens to kings of the Maurya and Gupta lines. Their capital was at Vaisali, which was already one of the most flourishing cities in India before Pataliputra was founded. It has been identified with

Basarh, near Muzaffarpur town. The Second Buddhist Council was held in this city. Excavations there have failed to reveal any trace of an ancient palace, but many relics have been found of the Kushan, Sunga, and even Maurya periods. There is a still more ancient site at Lauriya Nandangarh, where an Asoka pillar still stands. The excavation of some mounds at this place showed them to be burial mounds of the kind described in Vedic ritual. Sir John Marshall says that these are the only monuments now existing in India to which there is any warrant for ascribing a Vedic origin. North-east of Videha was Mithila. It was famous in ancient Hindu literature and was a great literary centre and Brahmanical stronghold in mediæval times, but there is very little reliable information regarding it prior to the seventh century, when Tirhut came for a few decades under Tibetan domination.

MODERN PATNA.

I will conclude with a few words regarding the origin and growth of modern Patna.

After the Afghan Sher Shah defeated Humayun in a battle near Buxar, in 1538, A.D., and so made himself Emperor of Hindustan, he caused a fort to be constructed on the spot where the ancient Pataliputra once stood. He did so, however, solely on account of the natural advantages of the site and without any idea of its glorious past. An almost contemporary Muhammadan writer gives a very vivid account of how his choice was made. He says :—

“ Patna was then an insignificant town, dependent on Bihar, which was the seat of the Governor. Sher Shah came to Patna and while standing on the bank of the Ganges, after a steady deliberation and excellent reflection, said to his attendants: ‘If a fort were built in this place the waters of the Ganges could never flow far from it, and Patna would become one of the greatest towns in the country, because the Ganges flows from the west and the river Gandak from the North falls into it with a strong current. The strength of the Ganges is broken so that it cannot advance towards the north.’ He therefore ordered skilful artificers and great architects to make an estimate for the construction of a fort where he stood. These experienced workmen submitted an estimate of five lakhs of rupees, which was immediately ordered to be made over to trustworthy persons. The fort was completed within a very short time.”

Sher Shah's prediction was soon fulfilled. The new Patna grew very rapidly and soon became one of the greatest cities in the empire. It was there that, thirty years later, Daud, the Afghan King of Bengal, successfully held out against the Mughals until Akbar took the field against him in person. Patna then became the headquarters of the Mughal governors of Bihar. It reached the zenith of its revived splendour when Aurangzeb's grandson became the governor and renamed it Azimabad, after himself.

The East India Company tried to establish a factory at Patna early in the 17th century, but the attempt was abandoned owing to the difficulty of communication with Surat. After the Company had gained a footing in Bengal a fresh effort was made and quickly proved successful. The chief article of commerce was saltpetre, then in great demand in Europe for the manufacture of gunpowder, but opium, musk, lac and other products were also freely dealt in.

After the battle of Plassey, Patna became the centre from which military operations in Hindustan were directed. It was twice besieged by the Imperial troops. On the second occasion the siege was raised by a wonderful feat of indomitable determination and endurance on the part of Major Randfurlie Knox, one of the greatest of the devoted band of little-known Empire builders to whom our present position in India is so largely due. In the blazing heat of an Indian April he led a small force from Calcutta to Patna, a distance of 300 miles, in thirteen days. In spite of the heat and clouds of dust Knox himself marched on foot every inch of the way in order to inspire his men and prevent them from grumbling. The very day after his arrival, while the Mughal commander was taking his midday siesta, Knox suddenly attacked him and put him to flight. A few weeks later he won a decisive victory over a force which many times outnumbered his own.

In 1763, when hostilities broke out between the English and Mir Kasim, the Nawab of Bengal, Mir Kasim captured Patna and caused its small British garrison to be massacred. His Indian officers refused to obey his order to kill them, and it was left to the Alsatian renegade, Walter Reinhardt, alias Samru, to carry out the work of butchery. Patna was taken a few weeks later by a force under Major Adams. It was again invested by the united armies of the Nawab and the Mughal Emperor. They were driven off and withdrew to Buxar where, on 23rd October, 1764, Major Hector Monro won the great victory which made the British undisputed masters of the Lower Provinces.

With the construction of railways and the consequent diversion of traffic from the Ganges, Patna fell once more into a state of decay. This continued until 1912, when it became the capital of the newly-created province. It is now the headquarters of the Local Government and has a High Court and a University of its own. Its long and chequered career has again taken an upward turn. Long may it grow and prosper!

THE CHAIRMAN, in proposing a vote of thanks to the lecturer for the admirable conspectus he had given of the ancient history of Bihar and Orissa, said that, personally, he found the most interesting portions of the lecture to be those where hints were given of contact with other parts of India and with the outside world. The first was the conjecture made by Rai Bahadur S.C. Roy that there were some remarkable resemblances between the Asur sites in Chota Nagpur and the

finds they yielded and those of the ancient ruins of Harappa and Mahen-jo-Duro in the Indus Valley. Nothing could exceed the importance of that contact if it were established, but he fancied a pretty quarrel might arise between those who attempted to establish that contact and the official view in regard to the matter, because he understood the official view was that in that eastern portion of India there were no remains which could be assigned to pre-Mauryan times. It was to be hoped that Rai Bahadur Roy would prove to be right, because in matters of archæology nothing was more important than such contacts. Those who had taken an interest in ancient history had had their interest enormously aroused by the contacts established in recent times between Crete and Egypt and the various civilisations in Mesopotamia, and it would be magnificent if it were possible to establish some evidence of contact between the remains in India and the remains of early times which were to be found in those great countries. There was another contact of which the lecturer gave a hint which aroused even greater interest when he mentioned that the Mundas, Santals, and Hos spoke dialects of the Austric family, the most widely diffused linguistic family in the world. It was spoken in many parts of south-east Asia and in islands of the Indian and Pacific Oceans as far as Easter Island off the coast of South America. He could imagine no discovery which would excite the archæological world more than if some contact could be established in fact and not merely in theory between Asia and America.

Then there was a possible contact brought out by Dr. Spooner's speculation that Asoka's palace showed some resemblance to the plan of Darius's palace at Persepolis. It was impossible to forget in that connection the wonderful speculations made by Sir Aurel Stein recently in the *Journal of the Royal Geographical Society* in connection with the site of Aornos, the strong height stormed by Alexander in his invasion of India.

These particular contacts were the matters which interested him most when he perused the paper, but he could well understand that in a paper so brimful of interesting matter others might feel inclined more to dwell on the fact that Bihar and Orissa was the birthplace of those two great religions, the Buddhist and the Jain. Again, Asoka was a name known even to a tyro in Indian history. He had been somewhat shocked when he read in the paper of the bloodthirsty way in which Asoka dealt with Orissa, because it did not accord with his own conception of that Constantine of Buddhism.

He thought the paper could not but arouse a certain amount of optimism with regard to the future of archæological work in India. When one saw how much was going on one could not forget the enormous debt that archæology owed to that great archæologist, Sir John Marshall. Twenty-six years ago he was first brought out to India by Lord Curzon for the purpose of superintending the preservation of the monuments of India, and during his career he had not merely revolutionised the whole upkeep of the great monuments of India, but had been responsible for the most interesting excavations at Taxila and elsewhere. It must be remembered, however, that Sir John Marshall could not last for ever. He had had 26 years in India, and it was to be hoped that others were being trained who would take the torch from him and carry it on in the future. Sir Edward had spoken of the Bihar and Orissa Research Society, and he hoped there might be other societies which would carry on the great work of archæological excavation. He was interested the other day at University College to find an Indian student had just left there who had been sent over to sit under Prof. Flinders Petrie in the Department of Egyptology to study methods of archæological excavation, and

that that student had been sent from Mysore with the deliberate intention that he should be able, on his return, to take over the archaeological work there. Personally he hoped many other States and Governments would feel it was their duty to do that work. There had been a wonderful spate of discoveries all over the world lately in connection with ancient times, and one would deplore it if India were to remain backward. He hoped such lectures as that which had been delivered by Sir Edward would spur people on to realise the great responsibility which lay upon them.

SIR CHARLES S. BAYLEY, G.C.I.E., K.C.S.I., said it gave him great pleasure to second the vote of thanks, and he wished in seconding it to propose at the same time an equally hearty vote of thanks to the Chairman for the honour he had done the Society in presiding that afternoon, and for the interesting remarks he had made.

When it was suggested that he should second the vote of thanks he undertook the duty with great diffidence, because he was painfully aware of his own deficiencies in the matter of historical knowledge. It was a long time since he left India and a great deal had been added to historical knowledge in the last 12 or 13 years. In justification of his diffidence, however, he might mention that when he was selected a candidate for the Indian Civil Service and was undergoing the tortures of a *viva voce* examination in Indian history, he endeavoured to excuse his deficiencies on the plea that he had done a great deal of other work, and also that he found Indian history an exceedingly difficult subject. He was rather nonplussed by his examiner saying, "Mr. Bayley, the genius required for studying Indian history is the genius of industry. I wish you good morning." There was, however, a great deal of truth in the remark. The lecturer had shown how much was owed to the labours of people like Sir John Marshall, Dr. Spooner and Rai Bahadur Roy, and, indeed, Sir Edward himself.

The lecture had given a wonderful idea of those great empires of Bihar and Orissa and their civilisation, and of the rising of one of the most important religions of the world. It showed the educational activity which existed in those times and the high state of civilisation which had been reached. He could not help thinking, when the lecturer referred to the emperors who had built Pataliputra and made it such a marvellous city, of the irony of fate which had left it to the speaker to found the modern city of Patna.

The proceedings then terminated.

CORRESPONDENCE.

STATHAM'S HISTORY OF ARCHITECTURE.

In your issue of March 16th, under "Notes on Books," referring to the second edition of the above with which my name was associated, there is a passage dealing with the authorship of Coleshill, which opens up an interesting subject.

There was formerly a tendency to attribute to Inigo Jones every good work of the period that could not be placed elsewhere, but recent investigations have modified a good many opinions formed on insufficient evidence.

In Mr. Gotch's "English Home," probably the most complete and reliable text-book on English domestic work, Coleshill is attributed to Sir Roger Pratt, and

evidence derived from a discovered notebook appears to establish the authorship of this building as given by Mr. Gotch.

I believe there is some talk of re-publishing the notebooks of Sir Roger Pratt, and I hope this will shortly come about, as they will make extremely interesting reading for students of this period of English Architecture.

G. MAXWELL AYLIWIN.

NOTES ON BOOKS.

MANUAL OF FOREST ENGINEERING AND EXTRACTION. By J. F. Stewart, F.R.G.S.E., Consulting Forest Engineer; Lecturer in Forest Engineering, Edinburgh University. With an introduction by Professor E. P. Stebbing, M.A., F.R.S.E., Professor of Forestry at the University of Edinburgh. London: Chapman and Hall. 15s. net.

The author states that this manual has been primarily written for Forestry students at the University of Edinburgh; and adds that he hopes it will be equally useful to all engaged in timber operations in any part of the world. The book is said to have been written from a practical point of view, and is intended for those who have no special training in engineering.

The actual amount of space occupied by the letter-press is 158 pages. Of this total, 22 pages are devoted to introductory remarks, cruising, exploring and camping; 72 to the extraction of logs; 21 to the felling of trees, their conversion into timber, and timber seasoning; less than five to cart roads; 12 to bridges; 22 to so-called permanent buildings; and 4 to forest operations in India. The amount of space allotted to different parts of the subject is not proportional to their comparative importance. For instance, more than four pages are devoted to dynamite and blasting, and 5 to trestles; while only 2 pages are given to roads, and less than 2 to wire ropeways. It is impossible to deal adequately with buildings in the 22 pages allotted to that subject. The author has set himself an impossible task in attempting to write even a simple manual, limited to 158 pages of letter-press, and it was inevitable that some portions of his subject should have been inadequately dealt with.

The extraction of logs is dealt with under the following headings:—The consideration of what constitutes a good floating stream (Chapter III); the improvement of floating streams, the working of logs down them, and rafting in slowly flowing rivers and lakes (Chapter X); transport of logs by land, on sleds, with low and high wheels, and on waggons (Chapter V); the Lidgerwood system of ground and overhead skidding and wire ropeways (Chapter VI); slides, chutes and flumes (Chapter VII); pole roads and tramways (Chapter VIII); forest railways (Chapter IX); the place of the caterpillar tractor in forest engineering (Chapter XIV). Cart roads are described in Chapter XII; trestles of various kinds in Chapters VIII and IX; and bridges in Chapter XII. Buildings and building materials are dealt with in Chapter XI; and forest operations in India in Chapter XV. Chapter IV is devoted to the felling and conversion of trees; and Chapter XIII to portable and semi-portable sawmills and the seasoning of timber.

In writing the manual, the author has not gone outside his own personal experience. Although not specifically stated, this experience appears to have been in North America and parts of Africa. This is a serious limitation to the usefulness of the book, as it means that none of the practical experience gained by European and Indian forest officers has been made use of. This is the more regrettable,

as both in Europe and India the methods of extraction developed have been those which are consistent with the preservation of the forests, a point upon which Mr. Stewart lays stress.

Practically all the information about extraction of logs and their conversion in sawmills is based upon the author's experience in America; a country where skilled workmen, both white and coloured, are always available. It has yet to be proved that these methods can be successfully carried out in parts of the British Empire, outside America, whether temperate or tropical. The Lidge-wood system of ground or overhead skidding is only possible where much larger quantities of logs are to be extracted from a prescribed area than is usually consistent with the preservation of the forest. The importance attached to caterpillar tractors is justified. The chapter on forest operations in India might have been omitted with advantage, as it contains no information of any practical value to a forest engineer, and some misleading and some inaccurate information.

The successful working of forest railways, tramways, and cart roads; of earth slides, chutes and flumes, depends primarily on their having been constructed with correct gradients and curves. The information given on these important subjects is most inadequate. The gradients and curves actually found on successful examples of roads, railways, slides, etc., should certainly have been given.

The differentiation between strut and truss bridge is unusual. The construction of the so-called strut shown in Fig. 122 (page 159) cannot be recommended, nor can the truss in Fig. 123.

The index occupies only two pages. This is not enough for a work intended primarily for students. Many terms employed in the book do not occur in the index. American logging terms have been freely used; and these require just as much explanation to those without knowledge of America, as do technical engineering terms to those who have no knowledge of engineering.

The book is profusely illustrated. There are 102 un-numbered pages, containing 136 illustrations, well reproduced from photographs. Of these 32 appear to be original; 47 have been supplied by manufacturing, logging and railway companies; and 57 by Colonial and the Indian Governments. Few of these illustrations are of much practical value in elucidating the text; and some are not even mentioned in it. These illustrations are, as a rule, too small to show details of construction, and nothing is printed under them to indicate what details they are intended to show. In addition to the above, there are 29 figures in the text, chiefly original drawings to scale, which are of more value to the forest officer; especially those to which letters have been added, which are embodied in the text.

GENERAL NOTES.

BURNE-JONES EXHIBITION.—A Burne Jones Exhibition will be held at the Fulham Central Library, Fulham Road, from April 21st to May 5th. Many interesting original drawings and paintings, reproductions, and Kelmscott Press books illustrated by Burne-Jones (including the famous Chaucer), will be shewn, besides personal things connected with his home at "The Grange," North End Road, Fulham. Arrangements have been made for the following lectures to be given in connection with the Exhibition :—(i) lecture entitled "Burne-Jones and his Circle," by Professor J. W. Mackail, M.A., LL.D., at 8 p.m. on Monday, April 23rd;

(ii) lantern lecture entitled "The Pictorial Art of Burne-Jones," by A. S. Renshaw, Esq., at 8 p.m., on Monday, April 30th. There is free admission both to the Exhibition and lectures, no tickets being required.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL. RESEARCH REPORT ON THE PRINCIPLES OF KILN-SEASONING OF TIMBER.—Numerous enquiries for advice on kiln-seasoning received at the Forest Products Research Laboratory appear to indicate that a summary of the principles underlying the drying of timber and a description of the more modern standardised types of drying kiln would be of value to those actively interested in this subject. The present report has been written with a view to meeting this demand. The process of drying and the consequent essentials required in kiln construction and treatment are briefly dealt with, and five common types of kiln are described with diagrammatic illustrations. The report concludes with a brief summary of the several factors which influence a commercial use of kilns, and the importance of trained operators being placed in charge of the seasoning operations is emphasised. The report is not based on the results of any individual investigation, but on practical experience gained at the Forest Products Research Laboratory and on the inspection of a large number of commercial installations in this country, Canada, and the United States. The report will be followed by others in which kiln instruments and various phases of kiln-seasoning practice will be discussed. The report can be obtained, price 9d. net, from H.M. Stationery Office, Adastral House, Kingsway, London, W.C.2., or through any bookseller.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, APRIL 2.—Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Dr. Hermann Muthesius, "Modern German Architecture."
Automobile Engineers, Institution of, at the Merchant Venturers' Technical College, Bristol. 6.45 p.m. Mr. J. N. Tait, "Mixture Distribution in Multi-Cylinder Engines."
Chemical Industry, Society of, at Burlington House, W. 8 p.m. Mr. C. D. Adams, "The English Sugar Beet Industry." Engineers, Society of, at Burlington House, W. 6 p.m. Mr. R. W. A. Brewer, "Air Cooled Radial Engines."
Farmers' Club, at the Whitehall Rooms, Hotel Metropole, S.W. 4 p.m. Mr. Herbert Greenfield, "Pool Marketing of Grain."
Geographical Society, at the Æolian Hall, 135, New Bond Street, W. 8.30 p.m. Mr. A. C. Hardy, "The Work of the R.R.S. 'Discovery' in the Falkland Islands Dependencies."
Royal Institution, 21, Albemarle Street, W. 5 p.m. General Meeting.
Surveyors' Institution, at the Institution of Civil Engineers, Great George St., S.W. 8 p.m. Mr. C. Dampier-Whetham, "Agricultural Depression: its Causes and Possible Cures."
Transport, Institute of, at the Institution of Electrical Engineers, Savoy Place, W.C. 5.30 p.m. Mr. E. C. Cox, "Southern Railway Electrification."
Victoria Institute, at the Central Hall, Westminster, S.W. 4.30 p.m. Mr. Avary H. Forbes, "Science in the Book of Ecclesiastes."
TUESDAY, APRIL 3.—Asiatic Society, 74, Grosvenor Street, S.W. 4.30 p.m. Dr. J. M. Unvala, "Excavations of the French Mission at Susa in the seasons 1926-27."
Automobile Engineers, Institution of, at the Royal Society of Arts, Adelphi, W.C. 7.45 p.m. Mr. E. A. Watson, "The Electrical Characteristics of Spark Gap and Sparking Plug."

Civil Engineers, Institution of, Great George Street, S.W. 6 p.m. Mr. John Goodman, "An Experimental Determination of the Thickness and Distribution of the Oil-Film in a Flooded Bearing."
North-East Coast Institution of Engineers and Shipbuilders, at Middlesbrough, 7.30 p.m.
Petroleum Technologists, Institution of, at the Royal Society of Arts, Adelphi, W.C. 5.30 p.m. Dr. Arthur Wade, "The Oil Well and later Developments at Hardstoft, Derbyshire."
Transport, Institute of, at the Imperial Hotel, Birmingham. 6.30 p.m. Annual General Meeting.
Zoological Society, Regents' Park, N.W. 5.30 p.m. Scientific Business Meeting.

WEDNESDAY, APRIL 4.—Analysts, Society of Public, Burlington House, W. 8 p.m. (1) Messrs. John Evans and T. E. Wallis, "Coffee Parchment as an Adulterant of Bran and Sharps." (2) Mr. W. B. Adam, "Determination of the Colour-producing Constituents of the Cacao Bean." (3) Dr. A. T. Etheridge, "Determination of Vanadium in Steel." (4) Mr. S. G. Clarke, "Colorimetric Determination of Antimony and its Separation from Tin." (5) Dr. A. Riad, "Determination of Carbon Dioxide in Soils."
Archæological Institute, at Burlington House, W. 5 p.m. Mr. R. A. Pelham, "A 14th Century MS. Map of Britain and its Influence on 16th Century Cartography."
Civil Engineers, Institution of, Great George Street, S.W. 6 p.m. Mr. G. T. Cotterell, "The Disposal of Sewage of Country Houses and Hamlets."
Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m.
Geological Society, Burlington House, W. 5.30 p.m.
Heating and Ventilating Engineers, at Watson House, Nine Elms Lane, S.W. 5.30 p.m. Mr. J. G. Clark, "Demonstration of Gas Testing and other Appliances."
Wireless Technology, Institute of, at the Engineers' Club, Coventry Street, W. 7 p.m. Mr. W. B. Medlam, "The Response of H.F. Circuits to Steady and Transient Modulation."

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICE.

SWINEY PRIZE.

The Council have to give notice that the next award of the Swiney prize will be in January, 1929, the eighty-fifth anniversary of the testator's death. Dr. Swiney died in 1844, and in his will he left the sum of £5,000 Consols to the Royal Society of Arts, for the purpose of presenting a prize, on every fifth anniversary of his death, to the author of the best published work on Jurisprudence. The prize is a cup, value £100, and money to the same amount.

The award is made jointly by the Royal Society of Arts and the Royal College of Physicians. In accordance with the arrangement with the Royal College of Physicians, the award next year will be for a work on Medical Jurisprudence.

Any person desiring to submit a work in competition, or to recommend any work for the consideration of the judges, should do so by letter, addressed to the Secretary of the Society, not later than November 30th, 1928.

A list of former recipients of the prize was given in the *Journal* dated March 23rd.

PROCEEDINGS OF THE SOCIETY.

ELEVENTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 8TH, 1928.

J. SWINBURNE, Esq., F.R.S., in the Chair.

The paper read was:—

THEATRE LIGHTING.

By HENRY D. WILKINSON, M.I.E.E., M.I.Mech.E.

The lighting of theatres has undergone notable developments during the last decade. Auditorium lighting, once a dazzling display of innumerable

points of light without shades or only partially shaded, is now generally planned with more pleasing effect by the use of a fewer number of lamps of high candle-power enclosed in anti-glare fittings. Gas-filled lamps have largely superseded vacuum lamps, both in the auditorium and on the stage.

On the stage the overhead lights (battens) and footlights (the float) of the open type, with only a white enamelled back for reflection, have given place to fittings of the magazine pattern with a separate compartment and reflector to each lamp, utilising the light to better advantage. The use of gelatine colour medium slides in this form of fitting has done away with the endless maintenance troubles associated with the colouring of lamp bulbs by the dipping process.

The high candle-power of gas-filled lamps now available (taking 500 to 1,500 watts or more) has almost resulted in the disuse of arc lamps for floods, projectors and spots, but arcs are still retained whenever a more actinic tone in the illumination is required for the scene, or for spotting from the front of the house when the throw exceeds 60 feet.

The subject of improvements in the lighting of the auditorium and illumination of the stage is intimately bound up with developments in the control and regulation of the current supplying the lights, and there is no doubt that careful planning of the technical equipment to secure safety and reliability as well as convenience in control is essential to the success of any lighting scheme.

The technical side of the equipment is by no means at a standstill; improvements are constantly being introduced and realised in new installations, and wherever existing installations are undergoing alterations or extensions.

At the same time, it cannot be overlooked that there are many theatres where out-of-date equipment continues in use. I therefore propose to include some notes on the lines of progress taking shape in equipments for the control of theatre lighting.

The voltage in use in theatres has risen from 100 (which was not long ago the general pressure employed) to 200, 230, or 240, and in many theatres the supply is from a 3-wire system in which case there is anything up to 480 volts between parts of the controls in connection with the outers, although of course only half that pressure is used for lighting. In Glasgow the pressure between the outers of the 3-wire system is 500 volts.

Electrical gear comprising the switches, fuses, and dimmers, &c., necessary for the control of the lighting has for many years suffered from being allocated to spaces totally inadequate for proper clearances in assembly and safety in manipulation. I have known the time when there was hardly any clearance between the stage switchgear and the artistes passing on and off the boards, and when what answered for a fireproof chamber was merely an iron casing on the stage wall enclosing iron wire resistance spirals suspended so close together that they touched when hot.

In present-day practice there is a vast improvement in the factor of safety when all resistances liable to become heated are housed in a fireproof and well

ventilated chamber. Room and adequate space has simply had to be found, for it is a natural law that even inanimate things, if they are to be developed to a higher state of efficiency, service and safety, must be given room for expansion.

In the regulation of stage lights great advances have been made in the method and apparatus used, both as regards convenience of operation and safety. I have known the time when the regulation of the stage lights up or down (dimming) was done by hand-operated multi-point switches, and when switch handles were connected by an improvised wood bar when it was required to dim all colours together. There was no such refinement as remote-control, and hand switches without carbon wipers were in use for currents up to 100 amps. The result can be better imagined than described. What with arcing and the numberless times the switches were opened and closed for black-outs and lights up, they were for ever falling into a semi-disabled condition, completely outrunning maintenance.

Those times have happily given place to safer conditions, but only after it has taken years to appreciate the necessity for more space and less cramped situations. Even to-day the clearances in many equipments are so limited that liability to shock or accidental connection is present.

The position can generally be greatly improved by the construction of a control platform on a gallery at a height of nine or ten feet above stage level. The switchboard and controls erected on this gallery then take up none of the valuable space on the stage, and the equipment can be laid out to great advantage for safe clearances and convenience of operation. It is not always practicable for the operator to see the effect of the changes he makes on the lights from this position, but pilot lamps, usually incorporated with the regulator, answer the same purpose. It should be mentioned that this position necessitates the signalling of cues from the prompt to the operator on the switchboard platform.

The position of the switchgear and controls at Drury Lane Theatre is at stage level adjoining the prompt, and therefore dispenses with the use of signalling cues. A convenient recess has been formed behind the stalls boxes for this purpose, and is arranged as a switch room with ample accommodation. In this position the prompt is in actual touch with the electrician. Cues can be passed by hand signal, and for any special colour effect instructions can be given by word of mouth without being overheard by the audience. Provided there is ample space for the gear, and that it is well out of the way of artistes, this is a very useful position, but is only practicable on very large stages and where the structural conditions of the building permit.

In the latest installations fuses are grouped in accessible and generally fire-proof positions, instead of being scattered over the house in all sorts of inconvenient places to save wiring. The long-standing problem of controlling the auditorium lighting from the stage has been solved. The practice of placing front of house switchboards in damp vaults and cellars at the nearest point

to the intake cables has been superseded by the provision of interior fireproof chambers, where switchgear has a chance of being properly maintained in dry and well-ventilated situations.

As the Authority for the licensing of theatres and places of public resort, the London County Council exercises jurisdiction over electrical installations in respect of safety from fire in such premises within the Administrative County of London. The last Code of Regulations issued by the Council in 1908 governing electrical installations in theatres is at the present moment under revision.

The Inspection Office of the Council is part of the Fire Brigade Department and technical officers highly experienced in theatre electrical work form the executive personnel of this Department.

Plans and specifications of new work or alterations to existing installations which it is proposed to carry out in theatres have to be submitted to the Council for approval, and when the works are completed must be certified by a competent electrical engineer as complying with the Council's regulations.

The regulations prescribe that the lighting of the auditorium, corridors, staircases, passages, exits, and all parts of the house open to the public, shall be from two independent sources of supply known as B and C circuits, the lights on each source to be as far as practicable half the total and at alternate points. Internally lit exit boxes must have a pair of lights, one fed from each source, and in no other position may the two sources of supply be contained in the same fitting, tube, or casing. They must be entirely distinct and separate systems, and the Supply Company's cables, meters and cut-outs are brought into separate intake chambers, and the distributing switchboards fed from each system are located in entirely distinct fireproof chambers.

The stage lighting must be from a third and independent source known as the "A" circuit, and there must be a stand-by supply from another source, with means of changing over to the alternative supply. In the event of failure of supply it is highly important to be able to change over to another set of mains, either belonging to the same or another company. The trouble may not be so drastic as a total failure, but a fall of twenty per cent. in voltage is quite enough to affect performances adversely and to become a cause of grave anxiety if dropped so much as to start contactors chattering. In the latest installations I have had contactors specially wound to actuate at any pressure down to 75% of full, and as an additional safeguard a push-on pull-off attachment is fitted to each contactor by which the circuit can be closed or opened by hand in the event of too great a fall in the supply pressure. This is more direct and obvious, and takes up less room than short-circuiting switches, especially where a number of contactors are in use. These precautions enable a tight corner to be got through, but if the pressure does not recover or drops to a further extent, the means for changing over to an alternative supply is the only thing to save the situation.

Where a duplicate supply is brought in for the stage, the stage auxiliary

lights are fed from the alternative mains, so that in the event of failure of the principal lighting there will be lights at the back and sides of the stage, the control platform, prompt, green room and staircases to basement and intake chambers, so that the staff can see their way about and the change-over made as quickly as possible. It also avoids any uneasy feeling on the part of the public that anything is happening not according to programme.

It is arranged that cables can be completely isolated from the change-over switch by means of connecting links, only one supply being linked-in at a time. An important precaution is that no second set of links must be anywhere available on the premises.

When changing over the switch is first opened to its mid-off position, then the links changed over to the alternative supply, and then the switch closed on that side. It is advisable to switch off some of the load before changing over and switch it on again in sections after connecting to the alternative source. It is important to see that the cables of the two supplies are so connected to the switch that the live sides on each set of mains correspond; otherwise, when the stage is shut down after the conclusion of a performance, switchgear normally on the high side will be on the low side when a change-over has been made, and the wiring up to the fittings will be left on the live side of the supply, which should always be avoided. The change-over switch and its connections are subject to the approval of the Council.

I found the arrangement thus outlined work smoothly enough on a recent occasion when a failure of pressure on the normal mains occurred during a performance. The change-over was effected smoothly in two minutes, including the time taken in descending to the intake chamber from the stage. During this short interval the stage was lighted by the auxiliaries as described, so that the public noticed nothing unusual. The next development will be for the change-over to be made by the movement of a single lever, all contacts being made in the correct sequence, with interlocks for full-proof action. This will save time and render impossible any mistakes.

The illumination of the stage requires very comprehensive planning as regards both intensity and control of lights. The footlights (float) and proscenium lights are the only real fixtures, but I classify overhead lights (battens or overhead floods) as fixtures, although they can be varied in height to suit the scene. Other lighting from fixed positions are the flood or spot lights, throwing beams from tier boxes in the auditorium, or from the stage perches. If a bridge over the proscenium opening on the stage side exists, or is intended to be constructed, floodlights in whites and colours can be used in that position to great advantage.

The movable part of the lighting can always be varied to suit the scene or play, and therefore the fixed part demands the greatest care in lay-out. In fact, the battens and float constitute the essential part of the illumination, and must meet all requirements of the producer and stage manager.

Producers set great value on that somewhat elusive but attractive feature called tone. This is dependent largely on the kind of reflectors employed, which may be silvered glass, stainless steel, or aluminium for the float, and either of the two latter for the battens. I have succeeded best in this respect by the use of aluminium reflectors.

Except in spectacular revues a comprehensive glare of white light over the whole stage is not aimed at so much as graduation in lights and shades. Various compositions and changes in the colours from battens and float go a long way, but the artistry in a scene is obtainable chiefly by skilful arrangement of whites and colours from the wing floods. Paintings by great artists are never flat; there is always a part in shade accentuating the eye of the picture, and the charm and illusion of a scene having the appearance of gradually receding into the distance is thus produced and made pleasing to the view. While on the subject of stage artistic work, I would like to pay high tribute to scenic artists. When it is understood that every important scene is drawn and modelled in miniature to scale beforehand, the work and skill put into the preparation of scenic cloths will be appreciated. I have been shewn small paintings of proposed scenes of such subjects as country villages, ducal gardens, and views of open country which were exquisite gems of art in design and colouring, and I am of opinion that no scenes in the world are as capable of being made so fascinating as those taken from the English countryside, nor can they be represented in a more skilful, pleasing and attractive manner than by the scenic artists among our own countrymen.

For good illumination of the stage I have found by experiment that the illumination intensity from the front at the centre point of the stage four feet above floor level should not be less than thirty foot-candles with white lights only. The illumination of the horizontal plane at this point (referred to as the focal point) from lights in front of it only, is in the proportion of 70% from the battens and 30% from the float. There will be battens behind the focal point and colours to consider, but if the white illumination from the front complies, then the other battens fall into line, and the general illumination will come up to this standard in all directions from the focal point.

If it is desired to plan the arrangement of battens and float to give this illumination intensity it can be readily calculated. The length of the battens will be a few feet longer than the proscenium opening and the float a few feet shorter. The working height of the battens will be known or can be assumed with close approximation. By summation of the triangular planes of light emitted from each source, and converging on the focal point and allowing 60 watts per 100 candles for gas-filled lamps, the loading for battens and float can be found. This generally comes out at not less than 120 watts of white lights per foot run. The wattage for colours will be approximately half that of the whites, assuming three colours, reds, blues and ambers.

Considering now stage lighting by moveable appliances, the great variety of effects requires a wide range of current obtainable by quickly accessible means. Several sub-circuits to carry 30 to 50 amps. for arcs, and many more for incandescents up to 30 amps. must be available by connection to stage floor plugs (dips or grounds).

The circuits for this purpose are wired in screwed conduit, and run under the stage, with outlet boxes containing the sockets immediately under the floor traps.

The sockets must not be fixed in a position to collect dust. The best arrangement is to fix them at one side, allowing just enough room for the hand to push the plugs in sideways (that is horizontally), thus leaving space for dust to fall clear. The plugs to have hand shields and side-entry for the conductors.

The arc and incandescent plug pins are, of course, at different centres, so that no mistake can be made.

The metal contacts in sockets attached to flexible cables should always be sunk at least $\frac{1}{8}$ " or surrounded by a projecting hood. Although this is such an obvious precaution against shorts, it is surprising how often one comes across flush sockets, not only in theatres, but elsewhere:

A large stage will also require facilities for obtaining heavier currents for special effects up to 100 amps. or more. For that purpose it is not practicable to use plugs, and the circuits are separately wired to ironclad boxes on or immediately under the stage provided with substantial connections, the current being adjusted for the stage setting at a disconnecting link box in the fireproof chamber, where resistances can be inserted when necessary. The special effect boxes are fitted with a pair of terminals on separate slate bases, with a dividing fillet and bushed outlet holes for the cables.

A great variety of effects are produced on back cloths and scenery by flood lighting from the wings with high power incandescents (of 500, 1,000 or 1,500 watts) mounted on portable standards with reflectors.

By the courtesy of The General Electric Co., two kinds of apparatus for flood lighting have been lent for this evening's paper. One is a powerful wing flood of very wide angle, mounted on telescopic stand, fitted with a 1,000 or 1,500-watt gas-filled lamp and a large reflector of polished aluminium with mottled surface. This is fitted with a glass diffuser and colour medium slide. Efficient ventilation is provided for in the design, and the vents are well screened. The other fitting is a new pattern projector lantern which is used chiefly for stage spot lighting. It is fitted with a 6" plano-convex lens of 9" focus. A $5\frac{1}{2}$ " dia. spherical reflector of special design is mounted, together with the lampholder and lamp, on a movable base, so that the size of the spot can be varied by adjusting the position of the lamp in relation to the condenser. A spot light attachment is provided for use with this fitting, incorporating an iris diaphragm by which smaller and more concentrated beams can be obtained without projecting the image of the filament.

Stage plugs for incandescents are arranged in connection with dimmers regulated on the control platform. The amount of resistance in the dimmers depends on the current; small currents require a range of high resistance, and large currents low resistance to regulate lamps from full to no light. It is sometimes required to light a single lamp or a small group for the setting of an interior scene, and if this is required to be dimmed on a liquid dimmer it can be done by a jar containing water only.

In large theatres where settings may be required for large, medium, or very small loads, it is convenient to have two or three circuits of plugs, so that the dimmers may be adjusted beforehand for each setting as required. Modern practice is to run a separate pair of wires to each socket controlled by a pair of 5-amp. fuses, instead of looping a number of sockets in one sub-circuit. The advantage is worth the additional wire involved, as, should a fuse blow, it affects only one of the floods in use, and the trouble can at once be located. For a certain scene there may be a bank of lamps taking 5 to 10 amps., for which one jar with metallic salts gives the range required. For a current of 30-amps. there would be required three jars in parallel. To meet these varied conditions I have employed liquid dimmers in groups of three jars simultaneously regulated on each of three stage circuits, with three S.P. switches to each circuit. With this arrangement any conditions required can be met and fixed up beforehand, so that everything is ready for each scene as it comes on.

By the courtesy of the Strand Electric and Engineering Co., I am able to shew a 4-way set of liquid dimmers mounted in a portable frame, complete with wheels and shafting; and also sections of battens and float of the magazine pattern fitted with colour-medium slides and lamps complete.

Illustrating the necessity of making the resistances inversely proportional to the current, the impossibility of regulation when the resistances are reversed will be evident. A single light cannot be regulated with a low resistance, nor can the bank with a high resistance.

Liquid dimmers give perfect graduation in lowering and raising lights. Wire-wound (metallic) dimmers must be sub-divided into 80 to 100 steps to give a graduation without flicker for metal-filament lamps.

A convenient form of metallic dimmer for assembling a large number in a small space is that of the Schwabe design. These are wound on rectangular frames, with a short vertical commutator over which the contact arm travels. It is therefore just as convenient for tracker wire operation as liquid dimmers. At St. Martin's Theatre these are set at about 5" centres. Metallic resistances should be graded and should have an open-circuit contact at the high end, and liquid dimmers should have the whole resistance short-circuited at the low end. Contacts for this purpose are usually incorporated with the regulator gear.

Nothing but the most perfectly gradual dimming will do for a dusk to night or dawn effect, and this can be done quite as well by 100-point metallic dimmers

as with liquid dimmers. The colours are usually amber, white, and blue dimmed in that order for one minute each in succession for dusk to night, and the reverse for dawn.

Dimmers which are used simply to bring a group of lights right up or right down without pause or check are not subject to any material temperature rise, and are treated somewhat differently to dimmers employed on checks. The latter may be required to keep a group of incandescent lights on half-light check for thirty minutes or more, and the break-down resistances for arc lamps may be in circuit for the entire duration of a particular act or scene. In opera a check of three hours' duration is no uncommon requirement. Such resistances (referred to in the regulations as the principal resistances) are housed in a ventilated fireproof chamber, reserved for that purpose.

The position of dimmers of the non-check class is subject to the approval of the L.C.C. Inspector, and if the conditions are favourable he may permit them to be mounted near to or as part of the main regulators on the stage controls. They are then enclosed in ventilated iron frames, and the switch arms connected mechanically by short tracker wires to the regulator, so that they can be worked singly or in combination with other similar circuits. Where there are a large number of principal resistances and long lengths of tracker wires with limited space for accommodation, it is a very great advantage to be able to mount dimmers of the non-check class in close proximity to where the main operations take place.

All dimmers, whether liquid or metallic, except embedded plate dimmers, are usually operated by tracker wires in combination with a set of regulating gear. This consists of a framework carrying horizontal shafts on which are mounted metal wheels grooved to carry the tracker wires. The wheels can be rotated through a half revolution by handles, which also serve to make the wheels fast or loose on the shaft. Each wheel represents a dimmer, and there may be anything up to fifty or more assembled. The grouping of the wheels is according to the colours of the lights, which are generally regulated down or up together. The horizontal shafts can be coupled together or worked separately, so that any desired combination of colours to suit the scene can be made. Individual circuits are controlled as required at the board adjoining.

Reference has been made to electrically remote-controlled dimmers which are either motor or solenoid operated. Motor driven dimmers of Messrs. Furse's design, fitted with push-button control, are used in the Capitol Theatre. These are arranged in pairs, with each pair balanced on the 3-wire 440-volt supply, and carrying a maximum of 70 amps. a side, complete with emergency contactors.

I have employed remote-controlled dimmers with solenoid operation, and the makers (The Watford Electric & Manufacturing Co.) have kindly loaned one of these for demonstration. It can be operated by a 5-amp. pilot switch or small relay at any distance. It will be seen that the resistance steps are

arranged vertically and cut out in sequence by the lateral movement of the rheostat bar. On closing the pilot switch the solenoid picks up the plunger against a weighted lever and withdraws the rheostat bar from the contacts, so gradually inserting resistance until the voltage on the lamps has been reduced to 15 % of normal. A small contactor then comes into action, interrupting the circuit; this being necessary because metal filament lamps will still be taking about 25 % of normal current although giving no light, on account of their negative characteristic.

When acting the reverse way on opening the pilot switch the plunger falls by gravity and the rheostat bar moves towards the contacts gradually short-circuiting the resistance units. On the last contact the entire resistance is short-circuited by a laminated brush at the top of the bar. *

A useful feature in the design is in the automatic cutting out of resistance by gravity. In the event, therefore, of a failure in the pilot circuit or the solenoid winding the lights are automatically brought up to full candlepower, without any manual operation whatever.

When it is required to dim the lights to half light only, part of the resistance is permanently shorted and the other part is continuously rated. Both full and half-light dimmers of this design of 40 and 20 amps. capacity respectively have been in satisfactory operation at the Alhambra Theatre for four years on the B and C systems of lights in the auditorium. The half-light dimmer is not, of course, fitted with an open-circuiting contactor.

The regulations stipulate that the main leads for circuit A shall where possible be kept entirely on the stage side of the proscenium wall, and those for the B and C circuits entirely on the auditorium side. It is, however, permissible to control a portion of the auditorium lights from the stage board that is to supply them with stage current provided a sufficient number of safety lights are maintained on circuits B and C in each portion of the auditorium entirely independent of the stage. The permissible lights comprise those for decorative purposes, which must be subject to the approval of the Council as to number and position.

As regards the auditorium safety lighting, it is only during performances that some of these are temporarily extinguished while the rest are left, some alight and some at half-light. At all other times the whole of the essential lights on both circuits are kept fully alight. To meet the scenic requirements these changes should be made at the exact moment that similar changes are made on the decorative lighting at the stage switchboard. The manner in which this has been done in the past, or attempted to be done, has undergone some notable developments. I first saw it done many years ago by the attendant on the stage board telephoning to the attendant on the auditorium board. It was impossible by this method to get simultaneous switching owing to the time taken in receiving and acting on an order by 'phone. The direct switching was then replaced by contactors with pilot switches on the proscenium walls,

so that the attendant could take his cues by visible signal from the man on the stage board, and by a touch on a few tumbler switches for changes, or a single master switch for black-outs, the cues could be followed pretty much as if made on the stage board.

This, however, was still not good enough, as there was always some time interval between the giving of a signal and its execution. In discussing the point with the L.C.C. Inspector, it was agreed that the remote control should be extended by the use of two-way and intermediate switches on the pilot circuits. These were to be placed in boxes at two or three positions in the auditorium, so that the lights could be switched on to full by the commissionaires in the event of anything happening on the stage. The principle underlying this development was that if means are provided by which the auditorium lights can be brought up to full at a moment's notice by an authorised person or persons who are always stationed in the auditorium, means may also be provided on the stage for the control of these lights.

I would like to place on record here the unstinted way in which I have always found the L.C.C. inspector to bring his experience and advice generously to bear in assisting those responsible when a technical point arises for solution. The wide experience of the inspector in things that matter and his knowledge of the inner meaning and intention of the regulations render his recommendations always most timely and helpful.

The two-way switches at the stage end on these pilot lines were then fixed in boxes on the auditorium side of the proscenium wall and operated by rods passing through the wall to handles on the stage board side. In this way the entire changes could be carried out simultaneously and by one man at the stage board. The final development then followed in turning the mechanical operation of the pilot switches into electrical by relay embodying the isolation precautions prescribed and including pilot lights sunk in the proscenium wall with a glass front on the stage side, so that no part of the auditorium wiring anywhere passed through that wall.

This arrangement has proved itself about as perfect as it could be made, and as it complies with the regulations it is a most satisfactory solution, and has been in unfailing operation at the Alhambra Theatre for over twelve months.

When the voltage on a bank of vacuum or gas-filled lamps is reduced the candle-power falls off at a quicker rate than the voltage and current. For instance, half-light is obtained with a drop of only 20% of the normal voltage and 15% of the normal current.

If therefore, a bank of lamps taking 25 amps. at 200 volts is to be kept on check at half light for a time the resistance added to the circuit must be such as to lower the voltage to 160. The current will then be about 20 amps. and the resistance must be capable of standing this for one hour dissipating 800 watts at a temperature not exceeding 180 deg. F. Checks are seldom for more

than fifteen minutes, but I once had a demand for one of forty-five minutes, and as the metallic resistances in use at that time were of the embedded plate type they would not stand this period without excessive heating and a bank of liquid dimmers had to be put in through the week-end ready for the rehearsal on Monday morning.

Liquid dimmers on a prolonged load simply boil up and give off vapour, but there is no trouble of a burn-out such as would happen with metallics.

As checks are nearly always on the whites, it is an advantage to arrange the whites in each batten on two circuits regulated by separate dimmers. The lamps in each circuit are wired up alternately so that each half is distributed uniformly over the whole batten and a good half-light effect without the aid of the dimmer is obtained by switching off one of the half circuits. If that is not enough the light can be further reduced by the dimmers.

Dimmers of the embedded plate pattern are usually incorporated with the regulating gear. This arrangement has a distinct advantage where space is limited, but the plates are only suitable for non-check regulation owing to the accumulation of heat. They should be used at no greater load than two-thirds of their rated capacity.

They are wound for different ranges of current and generally rated as 12, 20, 30, 40, or 50-amp. plates. If a small group of lights taking 1-amp. or thereabouts requires to be dimmed it cannot be done with such plates alone. A separate resistance must be connected in parallel with the lights to make up the necessary current to suit the plate of lowest rating. Such a resistance is usually made up as a permanent fixture for this purpose and arranged with a multi-point switch in ampere steps, so that the appropriate resistance can be switched in to suit the current. A resistance for this purpose is usually referred to as a substitutional resistance, because it takes the place of a bank of lamps and answers the same purpose so far as current is concerned.

The main switchboard, at which all operations are made during performance for the control, selection and regulation of the stage lighting and certain lights in the auditorium, is the principal feature on the technical side. The design calls for a detailed study of all requirements specially in the matter of controls. All operations must be within easy reach of the attendant, and it must be possible to make all changes quickly.

In the design every precaution must be taken against liability to shock; the flooring is of teak or oak, and all switches are of the dead pivot pattern.

Regulation 19 points out the necessity of ample separation of parts at opposite potentials. In carrying out this stipulation due regard must be given to accessibility in manipulating the controls; that is, the board must not be extended so much as to impede the attendant in the quick handling of the gear. This is generally met by a dead-front board, in which a shield is fixed in front of the live gear, and the insulated switch handles are the only parts which can be touched by the operator. All live parts are at the back of the panels, and

the parts at opposite polarity are separated by a hard wood partition projecting eighteen inches from the back of the panels.

While on the subject of dead-front switchboards, I should mention the Pre-selective Board designed by the Westinghouse Company (manufactured by the Metropolitan-Vickers Electrical Co., Ltd.)* which is equipped entirely on the remote control principle and in which the arrangement of pilot and master switches is such as to allow of setting group lighting for the ensuing scene without interfering with the lighting in operation at the moment.

Double-pole contactors are provided to each sub-circuit, each controlled by two double-throw pilot switches. One of these is for closing and the other for open-circuiting the respective contactor. The contactors are fitted with a mechanical latch which holds them in the "closed" position, so that the pilot switch can be opened as soon as the sub-circuit is made, and it is then thrown over to the opposite position for group control by the master switches. The sub-circuits are controlled by a master switch and contactor for each colour, and these are collectively controlled by a grand master switch. When the latter has been closed on one setting, all the individual pilot switches are released for "Pre-selecting" the next scene.

A switchboard of this design is in operation at the Plaza Theatre, and is fitted at the back with dimmer resistances of the embedded unit plate form, the regulating handles being operated from the front and grouped with the corresponding colours of the sub-circuits.

One half of the switchboard is on the stage lighting and the other half on the auditorium decorative lighting. The supply is three-phase converted to two-phase by Scott-connected transformers, and the load is balanced.

I am strongly of opinion that contactors with magnetic blow-outs should be employed on the high side of the supply in all theatre equipments, whether 2-wire or 3-wire, for cutting in or out groups of lights when the current is 50 amps. or over, and for complete shut-down.

The contactors can be fixed anywhere convenient suitably protected by enclosures, each controlled by a pilot switch on the main board. A master pilot is also provided for cutting the whole lot of contactors in or out at one stroke. This is an extremely useful arrangement from the operating point of view, because the changes so often required of lights out or up are made simultaneously for all lights concerned. It is not practicable to do this on hand switches. Say, for instance, there are four colours with a switch to each group. Three switches cannot be opened simultaneously by hand, and cannot be linked because the independent action of each cannot be dispensed with. On the other hand, three tumbler switches in line can easily be operated together by hand.

With hand-operated switches a master switch, also hand-operated, is required for simultaneous cutting in or out of all groups of lights at one stroke, and if the separate groups take 50 amps. each, the master switch would have

* I am indebted to Mr. Ernest Mead of the Metropolitan-Vickers Electrical Co., Ltd., Research Department, for general information on this system.

to break 200 amps., which is too much for a hand switch on a stage board. In my view 50 amps. is the maximum for hand switches in stage work, and carbon wipers should be fitted to switches carrying anything over 30 amps. Coming back now to contactors used as suggested above, there is another important advantage besides that of the simultaneous opening or closing a number of circuits of lights, and that is the use of the master pilot switch when closing down. The operator becomes accustomed to the use of this pilot switch for black-outs, and instinctively uses it for the shut-down after performances. This ensures that the outers of the 3-wire supply or the live side of a 2-wire supply are interrupted, and the stage wiring left absolutely dead.

The necessity for the whole of the stage wiring being dead occurs not only when the house is shut down after performances, but when cleaning and general maintenance of the gear and fittings is proceeding, and liquid dimmers are being topped up. The hand-operated selective switches on the board controlling individual circuits are usually left closed according to the setting required for the opening scene in the ensuing performance, and there is no objection to this when the live poles of the mains are isolated by the contactors.

I have not referred to subsidiary lighting in submitting this recommendation in order not to complicate the proposition, but it is just as simple in operation when such lighting is on a separate contactor and pilot switch.

Where the main board is in a cramped position for lack of space both poles have to be brought in to it, but where space permits and contactors are used as suggested, the board may be on the one pole while the contactors are on the other pole or poles, and they can be fixed at a distance from the main board, so keeping opposite poles well apart.

The modern method of wiring up to the switchboard is to provide a sheet steel trough or duct, one side of which can be opened. All conduits from the lighting and dimmer points are screw-clamped to the troughing; the wires can then be crossed over inside as required to bring them exactly opposite their proper switch or fuse on the board as they issue through bushed holes in the trough or through short lengths of conduit. The trough should run to a position at the back where it will be accessible and clear of the board.

When the stage is on a 3-wire supply, the load is usually balanced by connecting the battens on one side and the float, dips and auxiliary lights on the other side of the system. In a large theatre with a heavy batten load if this does not make a satisfactory balance it may be necessary to split the battens; half approximately on each side. Balancing on a single fitting is of course inadmissible and quite unthinkable now-a-days, and yet it has been done in a London theatre (since re-wired).

The balancing of stage loads leads to a difficulty in the regulator when used with liquid dimmers. Like colours must be regulated together, and for this purpose the wheels operating a single colour are mounted on one shaft. The short-circuiting contacts, therefore, which are at the full voltage of the outers

are in too close proximity for safety. This contingency is met by enclosing each pair of contacts in a separate iron box. The contacts are then closed by the motion of a cam on each wheel, which pushes in a spindle against a spring at the moment when the cones in the dimmer are home.

In magazine battens the lamps cannot come in contact with drop scenes, as the framework construction is a protection. Consequently, the wire network guard used for this purpose in open type battens is not needed and no fine wire shadows come across the field. At the same time, guards must be provided to prevent collision with the heavy wood quarterings with which scenic cloths are weighted along the bottom edge. This is particularly necessary in theatres where the cloths and borders are so numerous that very little clearance is available between them and the battens.

High candle-power lamps in battens and floats are best wired in sub-circuits of 600 watts and not exceeding 1,000 watts, because if the circuits are too large too much light is cut out when a fuse blows. The present regulations allow 4,000 watts to a stage sub-circuit, but this will probably be altered in the revision. This small sub-division, of course, means a good deal more branch wiring, but it is distinctly worth the extra cost. There should be fuses, of course, on both poles of each sub-circuit, as defined in the regulations and in accordance with practice in force for many years.

The group of small wires in waterproof canvas hose is preferably taken up from the centre of the batten over a wood sheave to which the hose is made fast. The slack for raising and lowering then drops in a bight and the hose passes up again to the grid, where it is anchored. The sheave is attached by a bridle rope passing over pulleys on the grid down to the batten counterweight to which it is made fast. Thus, when the batten is lowered or raised, the sheave moves with it, lowering or raising the bight of hose automatically. This arrangement supersedes the old method of hauling up or letting down the bight by hand rope from the flies. At the top end it is a good plan to bring the branch wires from the battens into terminal boxes above the grid, where at any time disconnections for testing can be made. From the terminal boxes wires are then continued in conduit down to a double-pole fuse board in a central and accessible position. Probably this arrangement will be considered in the revision of the regulations, as it is certainly inconvenient and in my view unsafe to have fuse boxes in the grid or flies, where the saying, "out of sight out of mind," applies with considerable force. I have had occasion to dismantle and re-construct distinctly unsafe positions in such situations.

In the modern magazine battens and float a channel is incorporated at the back to contain the wiring. This is lined asbestic or other heat resisting material, and has hinged covers with fasteners. By this means the wiring can be readily got at without disturbing the lamps and reflectors.

The batten framework must be efficiently earthed. This is done by an insulated earth wire making good connection to the batten frame and run up

in the canvas hose along with the branch wires to the grid, where it is connected to the earthed conduit. The wire ropes by which battens are suspended must be insulated from the batten framework. Strong brown porcelain insulators are usually employed for this purpose. Should any circuit in the batten develop a fault causing the framework to become alive the leakage current will pass to earth by the earth wire and at the same time is prevented by the insulators from finding a path by the suspension ropes. Before these precautions were thoroughly understood the suspension ropes were not insulated and, many years ago, a case occurred in a London theatre where leakage current found its way to earth by the suspension wires. The wire ropes were burnt through and the batten fell on the stage; fortunately, at a moment when no one was under.

Regulation 38 provides that the metal work of fittings must be insulated from the circuits, but gives no ruling as to earthing. This point will doubtless be given attention in the revision. I would suggest the advisability of duplicate earth wires to such large fittings as battens and floats or, at any rate, connection at two points whether one or two wires are used, as against relying on a single connection which may fail.

The latest development in stage lighting has followed the direction of realistic representation of atmospheric effects such as moving clouds, moonlight reflections on water, sea waves in movement, snow and fire effects, the projection of landscapes, seascapes, and clouds, and the blending of a variety of colour tints representing the natural colouring seen at different times in skies and horizons. Some of these effects in movement can be produced by means of what are called "effect projectors," fitted with a projection lens and a group of semi-transparent coloured discs set in rotation by clockwork or small electric motor. The discs are usually of mica, coloured in various devices which, when rotated in combination, throw on the screen representations of fire, rain, snow, moving water and other effects. Moving clouds can also be represented by this device. By the courtesy of the Strand Electric & Engineering Co., Ltd., one of these projectors is on view.

While on the subject of lighting effects, I should mention the use of the ultra-violet rays of the arc in conjunction with fluorescent paint on the objects illuminated. Attractive displays can be devised by treating costumes with chemicals which fluoresce in different colours and illuminating them from mercury arc lamps concealed in the float, and fitted with screens of special glass to remove all visible rays. Ordinary projection arcs with the same screens and using 100 to 120 amperes may also be employed for this purpose and spectacular effects on stage costumes produced by this means at very small cost.

I hope that the scenic artist will still retain opportunities to continue his art, for it is in the skilled composition of natural effects that the idealistic, the

mystic and the romantic elements so essential in theatrical representations are most effectively brought into being.

There are already indications that a higher degree of illumination on the stage is wanted, and will be called for, in the future.

In the first place, a full complement of battens exists loaded to the extent indicated above, they have about reached their limit, and other means must be employed. Proscenium lengths have fallen into disuse but that position might be made more of by the use of three or four 1,000-watt flood-light fittings on pipe mountings, each side of the proscenium arch controlled on the switch-board and dimmed on the regulator, or a single fitting each side with colour slides operated by tracker wires.

The capacity of the float could be increased by the use of tubular gas-filled lamps, which could be set in a magazine fitting at 4-inch centres instead of 6-inch, as required for spherical bulbs.

As regards the overhead lighting, no fittings of greater width than battens can be used where the clearances between drop-scenes are limited, but where sufficient overhead space is available vertical flood fittings, known as "Acting area flood-lights," can be used with advantage. These floods take lamps up to 1,500 watts, and are fitted with spun aluminium reflectors. At the bottom is a hinged holder, carrying a glass diffuser, or colour slide, protected by a wire guard. The glass slides are made up in narrow strips, to prevent risk of breakage from the expansion due to heat, and in case of breakage the strips can be readily renewed. The design is intended for direct vertical flooding of the acting area, in which case the standard gas-filled lamp is appropriate, but where the light is required to be thrown towards the scene and the fittings are tilted, lamps of the horizontal burning projector type must be used. Another pattern in use for the same purpose is the "Arena" flood light.

These fittings have been used with success in the overhead position as described, arranged for adjustment like battens as to height and controlled and dimmed in the same way. In some cases they have taken the place of one or more complete battens, and in other cases have been fixed and operated in combination with battens for the purpose of increasing the illumination in special scenes. A pattern of acting area flood is made with a magazine to hold one white and four colour slides, intended to be operated by tracker wires, but useful as this may be in other positions, I do not consider the method of operation practicable for overhead stage fittings.

Some of the largest cinemas are being adapted for performances more or less of a theatrical character between moving-picture sessions. The stage for this purpose, although not on the same scale as a theatre, nevertheless requires to be well and attractively lighted. In large cinemas footlights and overhead lights may be required with dimmers, but a great deal can be done with a few high-power flood fittings, having a range of colours for front illumination of the stage, and a pair of spot-light projectors for following the performers. There

are many cinemas that might start with a simple outfit such as a five-colour system of illumination from a single high-power flood fitting with mechanically-operated slides. Where these can be used there is the great advantage of colour variation without a dimming apparatus, and without the amount of wiring associated with a circuit to each colour.

Remarkable advances in the design of lighting apparatus for the production of atmospheric effects have been made on the Continent, and are largely in use there.

For sky and horizon lighting Schwabe "horizon colour floods" are employed. These are somewhat long, lantern-shape fittings of cylindrical form with 1,000-watt tubular lamp. The glass front is semi-cylindrical for producing wide-angle flooding, and is colour-tinted. A group of these fittings having the varieties of tints required are fixed in one or more rows and suspended behind the proscenium arch.

The full equipment for sky and horizon colouring effects is known as the Schwabe-Hasait cyclorama, which requires a specially-prepared creaseless cloth set at the back of the stage in the form of a semi-circle. It is hung from a curved rail, and can be withdrawn and rolled up by motor when not in use. The lighting apparatus consists of a battery of the horizon colour floods described and three panorama projectors for throwing views on the cloth.

An ingenious mechanism for the production of moving clouds from photographs forms part of the cyclorama equipment when in complete assembly. There are two London theatres possessing this equipment in whole or in part, and the complete lighting system is in use at the Festival Theatre, Cambridge. The Cyclorama is, I think, more suited to classical plays and opera than for theatres in which the majority of performances are given in this country.

I have so far made no trials with this equipment, but I desire to give due place in the paper to these and any devices which have proved successful, so that general information may be available.

I have alluded to the scenic artist who in the execution of his work does not consider the time and effort expended so long as his finished work is a triumph, and I would add that electrical engineers engaged in the design, construction and executive operation of all that contributes to the success of theatre lighting may also, in my opinion, justly claim to be animated by the same spirit.

I wish to record my grateful acknowledgment of facilities for taking photos at the Alhambra Theatre granted by the general manager and the stage manager and for the apparatus and slides placed at my disposal by the following firms:—

The General Electric Co., The Strand Electric & Engineering Co., the Igranic Electric Co., and the Watford Electric & Manufacturing Co., and also to acknowledge the assistance of my colleague, Mr. P. S. Tasker, in checking the proofs of the paper.

DISCUSSION.

THE CHAIRMAN said there must be many who, like himself, had previously had no idea of what a complicated and elaborate business modern theatre lighting really was. The beginning of modern theatre lighting was, in 1886, in Vienna, when Colonel Crompton, with Mr. Hugh Stevenson, Mr. H. M. Leaf and Mr. Melhuish, carried out the first elaborate attempt at theatre lighting at the Opera House there. Sir Augustus Harris spent a month or so studying the subject there, and then introduced the lighting in Drury Lane, and the Savoy followed.

Another little piece of early history was that shortly afterwards the Lyric took up elaborate electric lighting. The consulting engineer there told him that he took the power from the St. James' Electric Lighting Company and installed a small gas engine for ordinary effects, and put on the station when they wanted a big current. Extraordinary economy was obtained by using the gas engine, and they were rather puzzled why. He (the Chairman) investigated the matter and found the gas engine was running all day and all night and the Company's main was not disconnected, so that they were pumping energy back again into the Company's main at the times when they did not want it, and taking it from them between 7 and 11 at night. Shortly afterwards he went to the St. James' Power Station and asked the engineer there about his pressure level. In those days the theatre was a very big customer, because electric light was not developed as it was to-day. The engineer said: "We have one most difficult customer. The Lyric Theatre is always putting their lighting on, taking enormous currents, and at the end of the quarter its account is almost nothing!"

MR. F. CHARLES RAPHAEL, M.I.E.E., said that not many years ago stage lighting—the wiring for stage lighting at any rate—was of the crudest possible description, and the apparatus was even cruder than the wiring. Great progress had been made recently, and what was particularly significant was the very minute attention given to small technical details.

The lecturer took the proportion of float to battens as 30 for footlights and 70 for top lights; *i.e.*, roughly half the effective candle power for floats as for battens. That was very interesting, because he had noticed that modern tendencies seemed to be to diminish the footlights more and more, and to extend the top lights. In showing his pictures Mr. Wilkinson had mentioned that 60 kilowatts could be taken from the top lights only. He thought that upset his proportion; because there was not likely to be about 25 kilowatts in footlights. It was a mistake to diminish the footlights too much and indulge too much in top lights and side lights. In the case of a play given by amateurs in one of the small London theatres, one of the features was a girl in a Salvation Army bonnet; and the plot, such as it was, turned on the extreme beauty of this lady. The proportion of top lights was much too large, and the proportion of floats much too small. The lady being rather a nervous amateur, bent forward rather more than a professional would do. Most of the side lights were screened from her: the top lights were screened from her, and she had reflected upon her a few footlights that she was facing. The result was she appeared to have an extremely long nose and hollow cheeks, and it was not until the next act, when her face was properly illuminated, that one could realize why all the men made such a fuss about her.

Another example was the lighting of the "Old Vic" before rebuilding. There, so far as he remembered, there were no footlights. There were lights in front, throwing light from the auditorium, and very good top lighting; and the result seemed to him extremely flat. For ordinary good stage plays which were more

than pure pictures, and in which the faces and the expression of the faces should stand out, he was rather sorry that footlights were falling into disuse. After all, he did not think the reason that footlights had been handed down by tradition was merely because in the early stages they could not stick the candles up in the air. He thought there was a real illuminating engineering reason for footlights which was appreciated in those olden days.

With reference to stand-by supply for stage lighting, he understood that if the main supply failed, it was necessary to switch the main off, change over, and switch on again, preferably gradually. He would be glad if the lecturer would tell them why the expedient which he had adopted in operating theatres in hospitals could not be followed, by which half the lights were on one supply and half on the other.

On the question of fuses and the question of remote switching, when Mr. Wilkinson mentioned the desirability of having fuses down below and not at the grid, he heard a remark *sotto voce*: "Yes, but there are very few theatrical managers who can afford it." Of course, if one was going to follow the exact regulations, which meant that the fuse had to be put on the circuit side of the switch, it meant an extra length of wiring. For an installation of the size the lecturer had mentioned, and of the careful design which a theatrical installation must have, he felt convinced that single pole fuses would be all that was necessary. It would save expense and complication, and save danger to a certain extent.

MR. L. G. APPLEBEE thought the lecturer had not laid enough stress on the space usually allowed by architects for the stage switchboard and its gear. In many cases the consulting engineer and stage lighting expert were often called in after the building had been begun, and found that the space allowed for the stage electrical control apparatus was appallingly small, with the result that the gear had to be crammed into an inadequate space. It should be possible to get to the back of a switchboard, whether it was of the open or dead front type.

He agreed with Mr. Wilkinson that switchboards placed like that at Drury Lane were as nearly ideal as possible. He would suggest to architects that the adoption of that system would be extremely beneficial not only in the installation of the apparatus, but in the working of the same. To be ideal, the space under the stage floor immediately below the switchboard should be reserved for the dimmers, whether of liquid or metallic type.

The lecturer had mentioned the Continental system, the Schwabe-Hasait, and the fact that two London and one provincial theatres were fitted with this apparatus. There was an English system which was on very similar lines, namely, that devised by Captain Oliver Bernard, O.B.E., M.C., the artist, and Mr. Philip Sheridan, and installed in the Admiralty Theatre, at the Government Pavilion at Wembley, for the spectacle of the naval attack on Zeebrugge. The cyclorama was constructed of brick and plaster and flooded with 40 panorama flooding lanterns of 1,000 watts, each with colour screens to obtain the sky and horizon effects.

Motor driven clouds and similar effects were projected from a bridge on the proscenium arch. The whole of the apparatus was of English manufacture. He noted the lecturer said that "The reflector in the floats may be silvered glass, stainless steel, or aluminium for the float, and either of the two latter for the battens." He would like to know why he had ruled out glass reflectors for the battens. If it was for fear of breakages it should be remembered 36 theatres in London and the provinces used glass reflectors in their battens, and the breakages had been practically nil. Even in the London Hippodrome, where Mr. Julian

Wylie used to crowd the space between the battens with endless sets of cloths, there had been no breakages, and they had been working six years. If the silvering was done in a proper manner, peeling owing to heat would not occur. It was far easier to clean glass than polished aluminium, which after a short time went black and required re-polishing, whilst the glass only required a leather or duster. The only other objection that he could see was as to its efficiency, and that, he maintained, was far higher than that of polished aluminium. The A.L.M.A. Handbook on flood lighting gave the reflector factor of silvered glass as 90 per cent., and polished aluminium as 70 per cent., so that the objection could not be on the ground of efficiency. He would therefore like to know why silvered glass reflectors might not be used in battens.

As to the "tone" being dependent on the kind of reflector used, the lecturer said he had had best success with aluminium. Personally, he maintained that silvered glass with a broken surface was to be preferred. He thought the lecturer had put forward a scheme which to the theatre that could afford it was ideal, both from a technical and a practical view, with the exception of those small points that he had mentioned.

MR. HEYS JONES, after thanking the lecturer for his delightful paper, said it was not compulsory to instal a supply of current from two separate supply authorities. That was very useful in the middle of London, but in outside districts and in the provinces he was afraid it would be almost impossible to have two clear and distinct sources of supply.

The question of changing over, which was a very big point, had not, he thought, been considered carefully enough. There was no reason why a supply of current from two supply authorities should not be installed on the stage, but it complicated switchings and increased the risk of shock. He feared that no efficient preparation was made for changing over from one source of supply to the other. The new regulations of the London County Council would, he hoped, deal with the question of "earthing", and also would make the I.E.E. Regulations the basis of *their* new regulations, of course with certain additions and subtractions to meet the special conditions of premises licensed by the Council. At present the Institution rules were not law in any way. As to the question of lighting, he thought the public were not considered nearly enough. For instance, lights were installed which dazzled the eyes of a person sitting in the gallery, the circles or the stalls. That defect could, he thought, be very easily overcome. He believed that, especially in cinemas, the whole orchestra should be made to go up and down. The band could be accommodated on a platform, and when it had done its turn, down it would go.

A good deal had been said on the question of the crowding of machinery and plant. Almost the last thing that was considered by the designers was the lighting and the engineering part of the theatre. He thought that the lighting should be one of the first things considered, before even the box office. Money could be taken at the door, but a theatre could not be opened unless lighting had been installed. The majority of theatres were very badly maintained. The lighting of the orchestra could, he thought, be enormously improved. If the light of the orchestra must be shown it should have the same tinge of light as on the stage, and then perhaps the public would not object to it. It could be wired up in three or four colours, if preferred, and if there were a red light on the stage the orchestra should be given a red light also. He might add that he understood that as a rule the L.C.C. only allowed exit notices to be internally lighted, and all other notices such as those of tea rooms and the like had to be externally lighted.

MR. CHARLES A. BAKER said that the Chairman had spoken of what was done in 1886 in Vienna. In 1887 he did a good deal of work in Milan in connection with the La Scala Theatre and the Dal Verme Theatre. The La Scala Theatre had a big electrolier with some 250 or 260 lamps in the middle of the auditorium. Some of the stage effects involved elaborate electrical planning: they were entirely dependent, in those days on fuses: by exercising care they never had an accident.

The lecturer had mentioned 30-ft. candles as a suitable light for the stage; and any such light as that, of course, was approaching diffused daylight. No doubt, as the lecturer had mentioned, a few years hence 30 would go up to 40 50, 60 and probably 100, and all to the good. It was very depressing indeed to have badly illuminated scenes in a theatrical display.

MR. CHRISTOPHER MAYSON said he was merely a student of music, but, as such he had come in contact with a very interesting theatre in London, namely, the Opera Theatre at the Royal College of Music. There he thought they could claim to have a rather unique lighting system, in that they had a somewhat unique stage to deal with. The theatre itself was underneath the Conservatoire, in fact, it was in the basement. There was practically no head room at all, no room for any flies or grid, or anything of that kind, and most of the battens were fixed. They could not be slung up or down. A great deal of use was made of the floats; he thought they were practically always in use. With reference to the control, the dimming apparatus, which he believed was either patented or on which patents were pending, was designed by a student of the College, and was hydraulic controlled. The designer timed the apparatus and found it could be dimmed down from full to a complete black-out in 35 minutes. In connection with the question of lighting the house, it was found that, by painting some of the roof dead black, reflections from the orchestra pit were prevented. The question of orchestra lighting was another different point. Speaking as a musician, he thought if the lights were changed in the middle of a show the orchestra would lose their places. As it was, the orchestra complained quite enough when they had just a dim green light.

MR. R. C. CLAY referred to his past 30 years' experience of theatres in London and the provinces. In the provinces he found that the electric lighting in some cases was in a most appalling condition, a state of affairs which could not obtain in London by reason of the L.C.C. Regulations. He thought another reason for the float not having been installed at the Old Vic. until the previous Monday was that one of the Shakespearean producers strongly objected to lighting by footlights. There was a very great difficulty there owing to the side lights, but they had now been altered and a short float installed.

MR. H. D. WILKINSON said that, in acknowledging the very interesting remarks of the Chairman, he would like to express his gratification that the Chairman drew attention to the work of the Pioneers to whom the country was indebted for the initiation of theatre lighting by electricity. At the same time he would like to point out that the Chairman was himself one of the leading pioneers in the electrical industry. There was hardly any branch in electrical and mechanical engineering which had not been lifted to a higher plane of development through his exceptional ability and his unremitting devotion to progress in science and industry.

Mr. Charles Baker's remarks bore on the same subject and, having had the privilege under his guidance of viewing his work in Milan in 1887, he was pleased

to claim him amongst the pioneers of 40 or more years ago to whose labours in theatre illumination they were indebted, and he was glad to note that the opinion of such an authority in respect of the upward trend in the intensity of stage illumination confirmed the view expressed in the paper.

Mr. Charles Raphael's remarks were a valuable contribution to the technical side of the subject, and he was indebted to him for pointing out a slip in the paper on the size of earthing conductors.

His suggestion, that the proportionate illumination from the float and battens which was given in the paper was upset by the fact that the battens carried a total load of 60 kilowatts, was obviously made under a misapprehension of the conditions in the paper. The illumination was observed from white lights alone, and only from battens in front of the focal point, whereas the 60 kilowatt load was on the entire batten equipment of the stage, and included three colour groups as well as white lights. It also included the load on whites and colours in battens at the back as well as in front of the focal point. Furthermore the percentage given referred to the illumination and not to load. The loading on these fittings was not in the same proportion as the illumination from each source on account of the diverse positions in which the battens and footlights were placed in relation to the point of observation.

Mr. Raphael's remarks on a proper balance between footlights and top lights, and the mistake in amateur performances of too little illumination from the former, were very much to the point. In theatres, however, great attention was paid to the absence of marked shadows on the actors' faces, and the reproduction, as far as possible, of daylight effects. In some plays footlights were dispensed with altogether, but compensation in such cases was always provided by flooding from the auditorium. An example might be seen of this at the present time in the play "Uncle Tom's Cabin" at the Pavilion. This treatment was adopted a good deal in classical plays where not only were the footlights dispensed with in certain scenes, but the stage was extended over the orchestra. The footlights were then removed altogether or made to disappear, and the front lighting was effected by floods and spots in the auditorium. Disappearing footlights were in use in the Arts Theatre, London, and the Welwyn Garden City Theatre, the latter being famous in connection with the Amateur Dramatic Society (winners of first place in this country in the British Drama League and of the American Belasco Cup). The footlights in these theatres had been designed by The Strand Electric and Engineering Co. to turn over, so that the float entirely disappeared below stage, and the reverse side, which was then uppermost, was a section of flooring fitting flush with the stage. The apron was then fixed in front extending the stage floor over the orchestra. For classical plays at the Old Vic. Theatre the footlights were made removable and taken right away when the stage extension floor was in use. But these special cases in no way bore out the suggestion that footlights were falling into disuse; there was, as Mr. Raphael properly remarked, an illuminating-engineering reason for footlights, and unless compensating lighting from another source was provided they could not be dispensed with.

Mr. Raphael raised an interesting point in the amount of lighting on the stand-by supply, and asked why an equal division of the whole load on each supply was not followed in theatre practice as in hospitals. This was already done in the lighting of the auditorium as explained in the paper. The load was divided equally on the B and C circuits which were fed from independent sources of supply, but it would be a very different proposition to divide the stage load between two supplies in the same way. The controls for stage lighting must be within reach

of the operator for quick action, and in order to isolate all connections and apparatus on the two sets of mains, to avoid risk of cross connection and shock, it would be necessary to provide such clearances as would inconveniently increase the space occupied from the point of view of operation. The entire stage wiring would have to be arranged so that no wiring on the stand-by was in the same conduit as the main supply, thus duplicating the runs and increasing the cost and complication to an impracticable degree. Mr. Heys Jones, in his remarks, bore out the view that complicated switchings and danger from shock would be liable to result from such use of the stand-by supply on the stage.

As regards the recommendation in the paper that fuses should not be grouped in such places as the grid, where they were out of sight and out of mind, and at such a distance that replacements could not be made promptly, he was well aware that theatre managers like other business men would object to the cost unless they saw a distinct advantage, but his experience was that when the situation was clearly put the management would agree when convinced of the increased safety which such an arrangement afforded.

On Mr. Raphael's suggestion that single-pole fuses would suffice on sub-circuits and effect a saving in expense and complication, and to a certain extent minimise danger, he would say that in view of the necessity for double-pole fuses, where both poles of the supply were insulated, and also the advantage of their use where a fault occurred in the lamp or holder, or between the conductors in a twin flex without making earth, a very clear case would have to be made out before fuses on the neutral or earthed side of the supply were dispensed with.

Mr. Applebee had emphasised the importance of space for electrical controls, and he was glad to be supported in that argument by one so cognisant of the conditions obtaining in many London and provincial theatres. In the interest of the theatre and the public the electrical engineer should be called to co-operate with the architect in all new propositions, with a view to seeing that suitable spaces were provided for the controls, the wiring runs, the fire-proof chambers, and ventilation ducts to discharge outside the building.

He shared the pleasure of the meeting at Mr. Applebee's announcement that sky and horizon effects were now produced by apparatus of British manufacture equal to the Continental cyclorama.

As regards the use of silvered glass, reflectors of this kind had, no doubt, a higher efficiency than aluminium, but he did not recommend them for battens on the score of the many breakages he had experienced from collision between the weighted ends of scenic cloths and these fittings. At the same time this type of reflectors had a wide field of use for battens where the clearances were such that no risk of breakages was incurred, and where the tone of illumination met the demands of the management.

Mr. Heys Jones's contribution to the discussion from his own unique experience in theatre equipment was particularly valuable. There was no one more qualified to speak with authority on the strong and weak points in the electrical equipment of theatres, since his high office gave him the widest opportunities for observation. He would like to say that his official contact with Mr. Heys Jones had impressed him not only with his masterly acquaintance with detail, but chiefly with his willingness and unfailing courtesy in assisting with suggestions the work in hand whenever his advice had been sought, or he had himself sensed a situation of difficulty which his recommendations could help to solve.

His remarks on the subject of loading and changing over to the alternative supply, and also in regard to earthing, were a valuable contribution to the dis-

cussion. He was also glad that Mr. Heys Jones had raised the question of efficient lighting in the auditorium, and had drawn attention to the misplacing of units which from their position so often acted as blinders rather than aids to vision. In the public interest more attention ought to be given to the selection of the positions and efficient shading of lights.

As regards orchestra lighting, he had not met with objections where the individual fittings over the stands were of such a design as shaded the lights properly. There was a great deal in favour of Mr. Heys Jones's suggestion of a disappearing orchestra. The musicians were in some plays required to be seen as well as heard, while in others it was just as important for them to be heard and not seen.

The subject of maintenance raised by Mr. Heys Jones was most important. He had personally passed through several periods greatly differing in the degree of attention given to keeping switchgear clean and in good order. In some cases the electrician had appeared to have no other interest than in operation, while others had taken a pride in maintaining the gear under their charge in spic and span condition, and while periodically testing their circuits had traced out and removed small faults as they occurred. An electrician of this kind he held in very high esteem; he was a great asset to a theatre.

Mr. Christopher Mayson's remarks were specially interesting as showing what could be done where limitations in area and head room precluded many of the advantages of adjustment in position of stage lights.

Effective use was made in the Opera Theatre at the Royal College of Music of overhead flood fittings, perch spots, and footlights. Owing to the absence of an upper circle or gallery there was no sight-line preventing the use of projector lights in the auditorium ceiling, and a bank of these were employed with good effect in the front lighting of the stage, screened from the public.

The device in connection with the dimming apparatus referred to by Mr. Mayson as designed by a student of the College was very effective in giving control in speed of dimming. Oil pressure was employed acting on a small piston in a cylinder in combination with each resistance unit. The speed of travel of the piston was controlled by a hand regulating valve and the movement was transmitted to the respective resistance units by tracker wires. By this device very slow graduations of lighting and blending of colours could be carried out as required to produce a natural dawn or sunset effect.

Mr. Clay's remarks on the condition of electric installations in provincial theatres were of great weight, coming from one so greatly experienced in theatre work. He had thrown light on a situation that called urgently for a thorough system of inspection in theatres not at present under any regulations. The London County Council had led the way and the County Councils all over the country should not delay in formulating safety measures and in seeing that they were carried out for the protection of the public, as, in fact, had already been done by the Middlesex County Council.

NOTES ON BOOKS.

HISTORY OF ART. By Professor Joseph Pijoan. Translated into English. Vol. III. Barcelona: Salvat.

This is the third and concluding volume of Professor Pijoan's survey of the history of art. One might expect that a book by a Spaniard on this subject would tell more about Spanish art than a book written, say, by an Englishman, but that it

would, perhaps, not altogether do justice to English art. Such anticipations are verified by a perusal of Professor Pijoan's book, but we can excuse his omissions on account of the most interesting sections he has devoted to the art of his own country.

Although Reinach's "Apollo" is not superseded by this work, this is a more fitting size for a history of art. Professor Pijoan's judgments and comparisons are often more stimulating. His remarks may sometimes ring a little naïf; they are really full of good sense. "Raphael," he says, "like Mozart, whom he resembles in many other respects, while he produced works of a sort that are exceedingly judicious, also composed scenes filled with inspiration." Certainly, judiciousness and inspiration are the two poles of good art, just as order and liberty are the apparently, but not really, antithetical ideals between which the political community uneasily oscillates. Recent art criticism may seem to have over-emphasised the importance of judiciousness, perhaps because we live in an age of connoisseurship rather than an age of creation. Raphael was inspired; he was also exquisitely sophisticated; some of his work, both in paint and stone, combines the two complementary elements as only a man of the highest genius could have made it do.

Chapter XI, the Spanish Renaissance, is particularly worth reading. The persistence of the style known as Mudejar, through the sixteenth century and down to the present day, is an interesting phenomenon. This style is described as a Castilian adaptation of Burgundian Gothic; it is a sort of Baroque which is not a development rising out of the classical revival. The Plateresque was a more purely national style. A famous example is the Hospital of the Holy Cross at Toledo. "The doorway is flanked by pilasters which continue into the curve of the archivolt, while above is a little temple with statuettes and candelabra. It is just the sort of thing a goldsmith might have done." (*Platero* actually means silversmith). Foreign motives were used in Plateresque decoration, but the effect of the whole was always unmistakably Spanish. Then in due course Italian influences began to make themselves felt. The façade of the palace of Monterrey at Salamanca shows them; the palace of Charles V at Granada embodies them. In discussing the Escorial, Professor Pijoan is not unnaturally moved by pride to minimise Italian influence, and to make much of Herrera's work.

Different parts of Spain reacted differently to what was called the "Greco-Roman" style. Valencia was friendly, Catalonia cold. It was otherwise with Baroque. Once the style had been introduced "all Spain was rebuilt, we might say, with twisted columns, brackets and ornamental abutments." It is satisfactory to find Professor Pijoan championing all but the extreme manifestations of this beautiful type of expression.

DRAWING, DESIGN AND CRAFT WORK FOR TEACHERS, STUDENTS, ETC. By F. J. GLASS. London: B. T. Batsford, Ltd. 12s.

It would be unjust to approach a book of this kind in too highbrow a spirit. Yet how can one avoid shuddering at some of the expressions of taste with which Mr. Glass relieves the technical seriousness of the majority of his pages? Of G. F. Watts we read that: "reproductions of his work are always available, and the teacher might profitably spend a little time in talking about the work of this, possibly the greatest artist since the Renaissance." Nor is beauty to be briefly defined as "perfect fitness." Ruskin's remarks quoted on pages 164 and 165 appear to have no meaning. Ruskin says of the bow of a simple boat: "The sum of navigation is in that . . . You may magnify it or decorate it as you will: you do not add to the wonder of it. I know nothing else that man does which is perfect but that." This is temperamental but not poetic. It was very different for Keats

to write that "a thing of beauty is a joy for ever." Here is a phrase which, taken literally, means nothing, yet which is full of significance, and provides a far better definition of beauty than "perfect fitness." What is a beautiful picture—"perfectly fitted" for except to be "a joy for ever?"

On the other hand, one turns eagerly to Mr. Glass for his recipes, as (under gesso): "boil together one part of powdered resin, four parts of linseed oil, and six parts of melted glue, mixing well." Also for his general information, as (under metal-work): "gold is so highly malleable and ductile that leaves of one two hundred and eighty-two thousandth part of an inch can be beaten from it, and a grain can be drawn into 500 feet of wire."

The technique of the arts and crafts cannot be taught popularly without the sort of accompaniment that Mr. Glass very efficiently provides. It is impossible to teach taste, however, and but for a fact which once came to my notice I should have added that it does not much matter whether Mr. Glass and other teachers hold up Watts or even Sir Luke Fildes as the greatest artist since the Renaissance. The fact in question gives me pause. An eminent painter of my acquaintance formerly earned his bread by teaching in a secondary school in London. He held up not Watts, but Cézanne himself, to the little boys. Perhaps as a result, a certain largeness of vision began to come into their work, and they drew more boldly and expressively than other little boys whose artistic efforts I have seen. They did not pretend to manage details, but they handled the general design with primitive vigour. P.B.

PHYSICS IN INDUSTRY: LECTURES DELIVERED BEFORE THE INSTITUTE OF PHYSICS.

Vol. V. By H. E. Wimperis, O.B.E., M.A., F.R.Ae.S., Director of Scientific Research, Air Ministry; and F. E. Smith, C.B., C.B.E., D.Sc., F.R.S., Director of Scientific Research, Admiralty. Oxford: The University Press; London: Humphrey Milford. 2/6 net.

The fifth volume of this series of lectures fully maintains the high standard of interest set by its predecessors. As on previous occasions, the lecturers are qualified to speak with the highest possible authority on their respective subjects, and they have succeeded in doing so in such a manner as to reach the understanding of those who are not specialists.

Mr. Wimperis, whose theme is the relationship of Physics to Aeronautical Science, begins with a short survey of the methods adopted by Government Departments, or some of them, in recruiting and organizing their research staffs. Great advances have been made in this respect in recent years, and Mr. Wimperis finds it possible to say: "For Government Departments to adopt university methods *in toto* would scarcely be practicable, but it is nevertheless needful to go a good way in that direction, especially in regard to individual freedom and the avoidance of the burdensome regulations usually associated with Government enterprise. I am glad to say that the event has shown that satisfactory arrangements in this respect can be made."

The main part of the lecture describes the most recent improvements in aircraft design, as influenced by the application of physics and mathematics. In many cases the existing theoretical knowledge is far from complete, and some curious assumptions and simplifications have to be introduced; but the results are infinitely superior to any which would be likely to arise from pure empiricism.

Most prominent in this field, naturally, is the problem of the lift and "drag" of aerofoils in general, whence by a slight transition we arrive at a discussion of the rotating wing. Some remarks follow on experimental wind channels, including

the high pressure channel recently constructed at Washington; and finally the lecturer describes the most recent investigations on the improvement of engine performance, particularly with relation to reliability, supercharging and the elimination of "knock."

Dr. F. E. Smith's lecture, entitled "Physics in Navigation," though of no less interest, is highly contrasting in scope, since his treatment is to give a general history of the subject rather than to confine himself to the latest advances.

He relates how the principles of physics have been applied in the various methods of fixing position and orientation at all parts of the earth's surface, both when heavenly bodies are visible and when they are obscured. Many of the methods, of course, are applicable in either event; but in the latter condition a greater part is played, or will shortly be played, by some of the more modern inventions such as directional wireless, duplex sound signals, electrical leader cable, etc. Some description is also given of instrumental and other methods for detecting the proximity of ice, though here it must be admitted that the practical results as yet leave much to be desired.

GENERAL NOTE.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH. REPORT ON THE ACCURACY OF COMMERCIAL SCREW THREADS.—The tables of tolerances for screw threads which were laid down by the British Engineering Standards Association some ten years ago have, in the last few years, been the subject of a good deal of criticism. On the one hand it has been asserted that the present tolerances are too fine for commercial production and that wider tolerances should be permitted, while, on the other hand, the tables recently issued by the American Engineering Standards Committee include a series of tolerances considerably finer than those laid down by the Association. The report now issued contains the results of measurements made at the National Physical Laboratory of a large number of screws and nuts taken from the current stocks of firms representative of the various branches of mechanical and electrical engineering. It shows to what extent the existing tolerances are actually worked to in practice and how far screw threads made to these tolerances, or otherwise actually obtainable commercially, are regarded as satisfactory by different classes of users. The Report, price 1s. 3d. net, may be obtained from H.M. Stationery Office, Adastral House, Kingsway, London, W.C.2, or through any bookseller.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

TUESDAY, APRIL 10.—Quekett Microscopical Club, 11, Chandos Street, W. 7.30 p.m. Mr. C. H. Oakden, "The Invention of the Micropolariscope"; Prof. W. T. Gordon, "Rocks of Organic Origin."

THURSDAY, APRIL 12.—Aeronautical Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 6.30 p.m. Dr. H. S. Hele-Shaw and Mr. T. E. Beacham, "The Variable Pitch Airscrew."

Metals, Institute of, at 83, Pall Mall, S.W. 7.30 p.m. Annual General Meeting. Mr. K. B. Pilcher, "Alchemists in Art and Literature."

Oil and Colour Chemists' Association, at 8, St. Martin's Place, W.C. 7.30 p.m. Mr. R. P. L. Britton, "False Equilibria."

FRIDAY, APRIL 13.—Astronomical Society, Burlington House, W. 5 p.m.

Chemical Industry, Society of. Joint Meeting with Birmingham Section.

Chemical Industry, Society of, at Manchester. Dr. R. H. Pickard, "Fundamental Researches in the Leather Industry."

Engineering Inspection, Institution of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 7.30 p.m. Messrs. R. P. Wilson and C. H. Parker, "Low Temperature Carbonisation."

Transport, Institute of, at the Town Hall, Newcastle-on-Tyne. 5 p.m. Annual General Meeting.

Malacological Society, Burlington House, W. 6 p.m.

Oil and Colour Chemists' Association, at Milton Hall, Deansgate, Manchester. 7.30 p.m. Annual General Meeting.

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*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C.(2.)*

NOTICE.

NEXT WEEK.

MONDAY, APRIL 16th, at 8 p.m. (Dr. Mann Lecture.) A. G. HUNTLEY, of the May Construction Co., Ltd., "Applied Architectural Acoustics." (Lecture I.)

WEDNESDAY, APRIL 18th, at 8 p.m. (Ordinary Meeting.) ALFRED C. BOSSOM, F.R.I.B.A., "American Architecture" (illustrated by lantern slides). PROFESSOR A. E. RICHARDSON, F.R.I.B.A., Professor of Architecture, University College, London, will preside.

PROCEEDINGS OF THE SOCIETY.

TWELFTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 15TH, 1928.

COMMODORE SIR RICHARD WILLIAMS-BULKELEY, Bt., K.C.B., R.N.R.
(Commodore, Royal Yacht Squadron), in the Chair.

THE CHAIRMAN, in introducing the lecturer, said his task on that occasion was a very easy one, because he saw so many Elder and Younger Brethren present who knew Sir Arthur Clarke perfectly well. To those who had not the honour of knowing Sir Arthur quite so well, he might introduce him by saying that he was the most successful beggar he had ever met. He had extracted over £1,500,000 out of the pockets of his friends for Seamen's Charities in a very short time, and had done it without causing them any inconvenience, which was extremely clever of him; and one would rather be inclined to add the question, "I wonder what he is at this evening?" So far as that evening was concerned, however, he was perfectly harmless, and would certainly prove most interesting.

The following paper was then read:—

TRINITY HOUSE: ITS HISTORY AND ITS WORK.

By CAPTAIN SIR ARTHUR CLARKE, K.B.E.,

Elder Brother of Trinity House.

The Corporation of which I am going to speak is, to give it its full and ancient title, the Brotherhood of the Most Glorious and Undivided Trinity of Deptford-Stronde. It is better known as the Corporation of Trinity House, London. I hope I may be able to include, in this survey of its history and work, some facts that are not common knowledge, and even possibly not within the knowledge of this learned company of the Royal Society of Arts.

Just one word before I go further. My subject is the Trinity House, *London*. Because a citizen of Hull, or Newcastle, might get up and tell you that there are more Trinity Houses than one. And so there are; and all are ancient Societies of Mariners. Formerly there were five—four in England, and one at Leith. The ones in England were at Deptford-Stronde, at Hull, at Newcastle, and at Dover. Of these, Dover no longer exists. Its connection in its day with the Deptford Corporation—the Trinity House, London, as it is commonly called now—has a bearing on my subject. It confirms our tradition that we had our beginnings in a Guild far older than the first Charter of our Incorporation. The Dover Trinity House boasted of privileges going back to the Conquest. One of them was the ancient liberty of piloting ships up the London river, for which it paid tribute of Poundage to the Deptford Guild. It paid that until the reign of James II; and we take it to indicate both the prior existence and superior rights of the Trinity House of Deptford-Stronde.

That is practically all I mean to say about the other Trinity Houses. They are a study in themselves; and just as ours are, so are their records—a bit of the fascinating history of the mariners of England. They come in here because the spirit of rivalry runs high as to which Trinity House is the oldest. In our romantic moments, we like to talk of being the heirs and successors of monkish bodies that were charged with the maintenance of lights and beacons by King Alfred. It may be so. The other Houses boast of their antiquity, too.

A book on the Trinity House, London, written in 1746, has bitter things to say of the bragging of Hull, which claimed to have had a Charter of Henry VI, 1458. Our first Charter is of Henry VIII, 1514. The author of the book took the trouble to go to Hull, to see "this boasted Charter," as he called it. He was annoyed to find that the Elder Brethren of Hull were gone to York ("forsooth!") to attend a County election. But he satisfied himself, on what appears to be fair evidence, that the Charter was *not* a Charter, but an instrument of association, under which the Hull Brethren were privileged to assist Distressed Seamen, and to maintain an Almshouse for Mariners. That would

appear to be similar to the pre-Tudor association of the Master Mariners of Deptford-Stronde as a society of Seamen who administered certain charities, and were empowered "to take knowledge of those who destroyed seamarks."

When the Corporation of Trinity House appeared in Court over a dispute in 1683, Lord Chief Justice Holt, who was then at the Bar, gave it as his opinion that it had existed, as a Company, prior to the Charter of Henry VIII.

The Charter of Henry VIII. was its Charter of Incorporation. It was granted to the Master and Wardens and members of the Holy Trinity of Deptford-Stronde, giving them "the authority for ever of making laws and statutes among themselves, for the relief, increase and augmentation of the shipping of England, and to meet and treat amongst themselves for the good state and conservation of their Guild and Fraternity; and of and upon all anywise concerning the science and art of mariners." It empowered them to elect a Master, Wardens and Assistants; and to own and acquire possessions; and to find a chaplain to celebrate divine service in the church of Deptford-Stronde.

Those are the privileges and duties of Trinity House as set forth in our first Charter. But the King went further than that; and his subsequent directions to the Corporation are of great interest. They laid upon the Trinity House the charge of the naval storehouse built by the Crown at Deptford; and of the building, keeping, and conducting of the Navy Royall.

The Trinity House, London, appears here, in fact, as the cradle of the Royal Navy. The child has long since outgrown the cradle. But the connection between the House and the Navy, once of paramount national importance has, though dwindled, survived into our own time. I am not referring to the inclusion of naval officers among the Brethren. I mean a lasting connection in our work. We are often in touch with the Admiralty in nautical matters, especially with its hydrographical department. Up till 1874 we examined the officers of the navigation branch of the Navy. They were formerly known as Masters and Mates. While those navigational ranks of master and mate R.N. survived, you had the descent, going back unbroken, to the incorporated master mariners of Deptford-Stronde who were "charged with the conduction of the Navy Royall."

It was, then, a privileged existence, and a responsible existence, that the Trinity House entered upon in 1514. Other privileges and responsibilities were to follow. In the eighth year of Elizabeth an Act was passed enabling the Trinity House to erect sea marks, and to levy dues on shipping for their maintenance. Also to license mariners to row in the Thames. The monopoly of Pilotage in the Thames was already in existence. In June, 1588, there is a reference to the privilege of exemption from service on land. We still erect seamarks—lighthouses, buoys and beacons—which are maintained by shipping dues collected by us; we still are the chief Pilotage authority of the kingdom; and we are still exempt from land service.

The rights of ballastage, and the dues levied for beaconage and buoyage, belonged originally to the Lord High Admiral of England. Many early grants by him of ballastage leases to private individuals are known. This farming out was an unsatisfactory business; and the Lord High Admiral Howard surrendered the entire rights into the hands of Queen Elizabeth, simultaneously beseeching Her Majesty to bestow them for ever on the Trinity House. The Queen's grant followed, acceding to the Lord High Admiral's petition.

Ballastage dues were for many years extremely valuable; but they declined and finally disappeared in the nineteenth century, when it became no longer necessary for the ships to take ballast. From 1853, the light dues, paid by ships of all nations using British ports, have been paid into the Treasury, after being collected, through the Custom House, by the Trinity House. The existing procedure is that the lighthouse authorities of the kingdom—that is, the Trinity House, the Commissioners of Northern Lights, and the Irish Light Commissioners—budget annually to the Government for their expenditure. That expenditure, including new works, and the progressive improvement of lights and other devices for the safety of the navigator round our coasts, is now round about a million sterling a year.

Before I go on with the history and constitution of the Corporation, I think I should say something about its name. Why Trinity House? Or rather Trinity Houses? The answer is that an appellation relating to the Trinity is not peculiar to Mariners' Guilds. The Universities, of course, know it very well. King Henry's Charter was, to quote the exact words, bestowed "out of his sincere love, devotion and affection towards the Holy Trinity"; and, as a pious monarch, he enjoined charitable as well as public and religious offices. And just in passing, I may say we continue our religious exercises, though no longer at Deptford-Stronde. If you go to St. Olave's, Hart Street, on Trinity Monday, you will find the Corporation at worship there.

The charitable duties we discharge also. Out of funds received, many of them, in bequest from past Brethren, the Corporation last year disbursed £22,708 mainly in pensions and almshouse relief for aged Master Mariners, their widows, and spinster daughters. The charitable trusts we hold have increased in value; and in the last 30 years the number of such beneficiaries has been more than doubled. The Almshouses we maintain are attributed to Wren, and are to be found in the Mile End Road. The Trinity House also subscribed last year nearly £500 to various seamen's charities; and it has a Fund for assisting with the outfit of poor boys who desire to go to sea. In addition to these charitable distributions of its corporate income, it allocated last year, out of monies granted for the purpose by King George's Fund for Sailors, £2,225 in special grants to seafarers in distress and their dependents.

The original Charter was suspended in the Commonwealth, when the Brethren were deprived of their corporate dues and duties. One can see, that to leave a powerful body with strong Royalist leanings, in authority over

ships of war and naval stores, would have been an act of political unwisdom, very unlike Oliver Cromwell. The Charter was renewed at the Restoration, and the Corporation repossessed of its full rights and privileges. The Charter of James II, following, is the one under which the Trinity House continues to function at the present time.

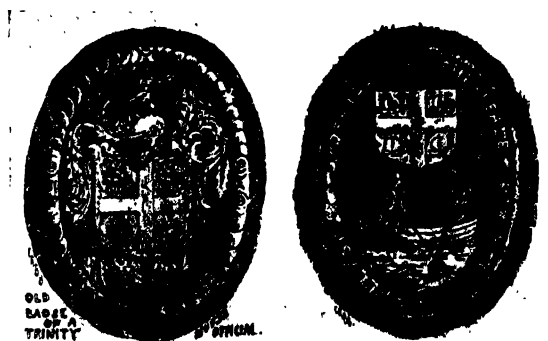


FIG 1.—Arms granted by Queen Elizabeth, 1573.

A grant of arms was made by Queen Elizabeth in 1573. The arms are—a plain cross gules, between four ships sable, and foresail and main topsails set. In this coat of arms the herald utilised the "ship sable" of Sir Thomas Spert, the first Master of the House, clerk-comptroller of the King's ships, and an eminent seaman of his day. His monument in Stepney Church displays the ship sable in his arms. It also displays the Tudor rose, and claims him as the founder of Trinity House.

Another distinction that was granted to us under the Tudors was our flag—a red ensign with four galleons in the fly. We are very proud of our distinctive flag. Some years ago the Navy offered us the privilege of flying the white ensign; but the Corporation decided that it would keep to its old flag. You may see it flying in the ships, light vessels, and establishments of the Trinity House; and when the King holds a naval review you will see it flying in the Trinity steamer, which is privileged to precede the Royal Yacht, a long-established honour relating to the Trinity House as the chief pilotage authority of the kingdom.

The dues and duties of the Trinity House were not secured to it without opposition, in Parliament and out of it. In 1617, the Attorney General found that the King was not precluded from erecting lighthouses, which gave His Majesty a chance of selling patents—an opportunity of which a Stuart monarch was naturally not slow to avail himself. Trinity House appealed unsuccessfully; and, in the next year, one Sir William Erskine secured a patent and erected a lighthouse at Winterton, exacting a heavy due from passing ships. Other people followed his example; and, private lighthouses were erected at Ravenspur, Dungeness and the Lizard. Apart from Trinity House,

there was objection to one of these private lighthouses from another quarter. The local inhabitants at the Lizard complained that it would "take away God's grace from them, as they will have no more benefit from shipwreck!" A less piratical objection to the Lizard light was brought forward by Weymouth and Melcombe Regis: "In hazy weather it cannot be seen; and in clear weather the land can be seen." A very logical argument!

Trinity House continued to oppose every patent for a private light. But private lighthouses continued until 1836, when an Act of Parliament empowered the House to purchase from the Crown and private proprietors all private lights then in existence. And that was the end of the 200 years' battle for the lights.

It is the duty of Trinity House to disperse wrecks dangerous to navigation round the coast of England and Wales. The first mention of this work is in 1636. During and after the Great War, as you will see by the chart on the screen, wreck dispersion became an undertaking of very considerable magnitude. The red dots are the wrecks. They were not all dangers to navigation, and so liable to dispersion; but there are quite enough wrecks to be dealt with, still, to keep us busy.

As I have said before, the Trinity House is the chief Pilotage authority of the kingdom. In the old Deptford days, as now, it supplied a pilot to every outward going vessel; and long before the sixteenth century there existed a branch establishment at Leigh in Essex, for supplying pilots for the incoming ships.

At the present day the Elder Brethren examine the licensed London pilots yearly, with a view to testing their sight and hearing, and their knowledge of any navigational changes in their particular pilotage districts. Our representatives carry out similar examinations in all other ports served by Trinity Pilots.

The recorded activities of the Trinity House touch the national history at many vital points. There were the thirty sail of merchant ships offered by the House to the Lord High Admiral in July, 1588, to be fitted in four days to proceed against the Spanish Armada. There were the persistent efforts of the House to assist in the suppression of pirates, who levied a disastrous toll on shipping, often close to the English coasts, in the seventeenth and eighteenth centuries.

No less than 300 English ships were captured by pirates between 1619 and 1621. Trinity House supplied £2,000 in assistance at this time, and collected a levy from merchant vessels for counter measures, defensive and offensive. It advised that merchant ships should sail in fleets—the convoy system, in fact. And for very many years the Trinity Brethren were concerned in raising ransom for seamen captives in Algiers.

In the wars with Napoleon, the Trinity House raised a volunteer force, the Trinity House Volunteer Artillery, with the Deputy Master as Lieut.-Colonel. From 1803 to 1805 the Brethren manned and commanded 12 frigates, which

were moored in the Hope for the defence of the Thames. There were two Brethren to each command ; so that these ships had the peculiar distinction of having two captains apiece.

During the late war, the Admiralty took over Pilotage jurisdiction from Plymouth to Great Yarmouth ; simultaneously appointing the Corporation to administer the service on their behalf. This involved the appointment of 150 additional Pilots. In addition to this, from May, 1917, to the end of the war, all vessels navigating between Berwick and Great Yarmouth had to be piloted by men holding the special Deep Sea Pilotage certificate. Under this order the Trinity House certificated over 300 pilots. The Corporation's work connected with lights, buoys and beacons was carried on as usual during the war. The principal Trinity steamer, the Yacht *Irene*, was mined and lost, with many of her crew, while discharging this duty off Margate in 1917. One or more of the Elder Brethren were always on duty in the Trinity House in connection with this work, by day and night.

The members of the Trinity Corporation consist of an indefinite number of Younger Brethren, and a number of Elder Brethren, elected from the Younger Brethren. The number of the Elder Brethren now is 24, 10 of whom, all seamen, constitute the Board and Committees and carry out the active work of the Corporation. The remainder are men of high place and distinction, and at the present time include His Majesty the King, H.R.H. the Prince of Wales, H.R.H. Prince Arthur of Connaught, past and present Prime Ministers, and First Lords of the Admiralty. The Master to-day is H.R.H. the Duke of Connaught, and the Deputy Master, who presides at the Board, is Vice-Admiral George Mansell. There was considerable controversy in days bygone over the election of landsmen Brethren. Samuel Pepys, Master in 1676 and in 1685, was one of them ; but he had, of course, an official connection with the sea.

A Bishop was once admitted a Younger Brother—the Bishop of Rochester in 1673, after preaching on Trinity Monday. One can only suppose he had given the Brethren something uncommonly pleasing in the way of a sermon ! Among the illustrious Masters and Brethren of the past we find Hawkins, Drake, and Frobisher ; Andrew Marvell, the poet ; General Monk ; and the Duke of Wellington.

In addition to their duties at the House and around the coasts, the Elder Brethren sit in rotation as assessors in the Admiralty Court—where they are known as the Trinity Masters. They also sit in the House of Lords and the Scottish High Court, on nautical cases. Trinity House sends a member to the Port of London Authority, and to the Harwich Conservancy, and to the Southampton Harbour Board. It has long been the established custom of the Government to apply to the House for an Elder Brother to sit upon such departmental Committees as are from time to time required to report upon sundry maritime matters. I need say no more about these advisory offices than that the Brethren, by virtue of their qualifications as Trinity Masters,

and as experts in navigational affairs, are well fitted to help in dealing with the special maritime questions that so often arise in our seafaring empire.

I will now touch briefly on the seamarks of the Trinity House—lighthouses, lightships, buoys and beacons—and their history. Setting aside such ancient structures as Caesar's Tower at Dover, the first references to a seamark may



FIG. 2.—Dover Pharos.

be taken from the Charter to the Trinity House of Newcastle-on-Tyne of 1536, and an Act of Elizabeth, 1566, both enjoining the necessity for maintaining beacons for the safety of the mariner. The first lighthouse appears to have been erected at Caster in 1600, followed shortly by two at Lowestoft. Harbour lights at Tynemouth and the Tees are also mentioned by Camden about that time. The first light, which was probably at Tynemouth, was a coal light, or open brazier. The next method was candle-light—hence the term candle-power. For the purpose of running quickly through the developments in the lighting of our coasts, I will show you the best known of the English lights, the Eddystone, in various stages of its progress.

First came Winstanly's Tower. It was begun in 1696 and completed in 1699, and was built of wood. It stood for five years, and was then swept away, its creator and all hands perishing with it, in the great gale of November, 1703.

The second was Rudyard's Tower of wood and stone, completed in 1709, and destroyed by fire in 1755. The third was the famous stone tower of John Smeaton, commenced in 1756, and finished in 1759. This tower stood for 123 years, and it was only the giving way of the rock beneath it that necessitated

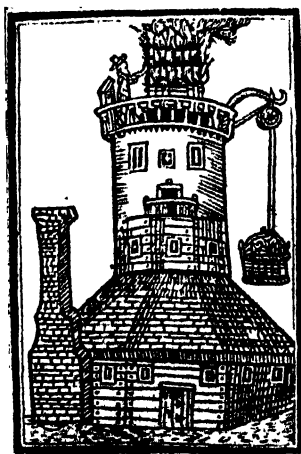


FIG. 3.—Coal Fire Lighthouse, Dungeness.

its demolition. It was, as a matter of fact, taken down and rebuilt on the Hoe at Plymouth, where it stands to this day.

The fourth and present lighthouse was begun in 1878 and finished in 1882. It was designed by Sir James Douglass, and the work was executed under his immediate direction. Its height is rather more than 170 feet, and the light is about 135 feet above high water.

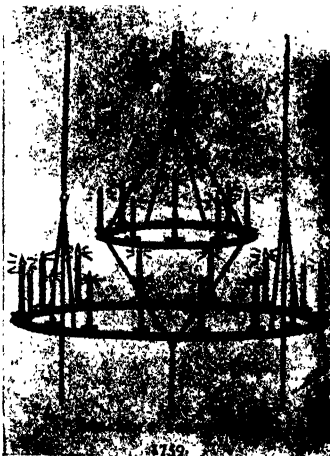


FIG. 4.—Smeaton's Chandelier.

Fig. 6 shews the old original Smalls Lighthouse at the entrance of the Bristol Channel. It was a wooden structure and was superseded by the beautiful lighthouse illustrated in Fig. 7. The next illustration (Fig. 8) is of the "Wolf Rock" lighthouse on the south-east coast, in a bad sea; the

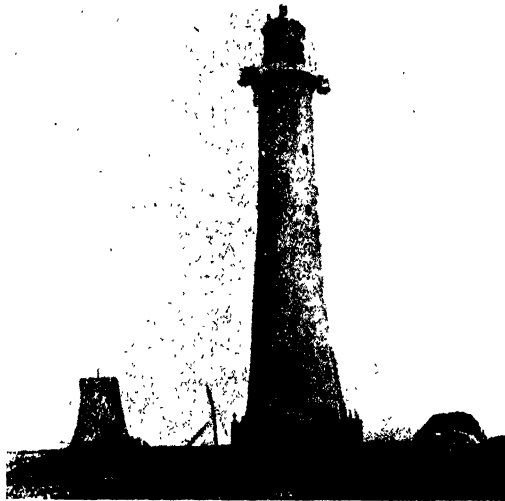


FIG. 5.—Douglass Eddystone Lighthouse.

crest of the sea has been known to go right over the lighthouse and wash away the ladder used for cleaning the glass of the lantern.

The first lightship (Fig. 9) was placed at the Nore in 1732. It had two braziers burning coal and was moored with a hempen cable. Fig. 10 shews one of our latest lightships, off the Royal Sovereign shoal in the English Channel, fitted with three anchors and every modern improvement, electric light with a candle power of 750,000, submarine oscillator and diaphone.

LIGHTS.

The pioneer in the development of optical apparatus for lighthouse illumination was Fresnel, who, in 1822, produced the first lens panel. This he built up of a central lens and a series of concentric annular glass rings, called refractors,



FIG. 6.—Old Smalls Lighthouse.



FIG. 7.—New Smalls Lighthouse.

which were in reality segments of lenses of varying diameters with the central portion, as it were, removed, for it would have been impracticable to make a large panel with a single lens, owing to the great thickness of glass involved.



FIG. 8.—Wolf Rock Lighthouse in a Sea.

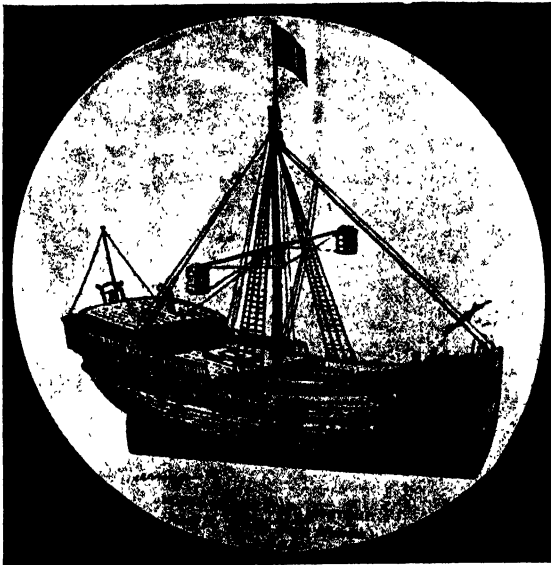


FIG. 9.—The First Lightship.

When a ray of light passes through a glass medium it becomes bent or refracted from its original course, and all the separate elements of Fresnel's lens were shaped and arranged so that they had a common focus and that the various rays of light emanating from a luminous source placed at that focus were diverted from their path and made to emerge from the panel as one solid beam of light on a line parallel with the axis of the lens.



FIG. 10.—A Present-day Lightship.

To the size of these panels there was a limit, for beyond a certain angle, known as the critical angle of glass, incident rays of light instead of entering the glass are reflected from the face of it. To overcome this difficulty, Fresnel introduced cylindrical prisms, in which the rays of light were first refracted as they entered the prism, then underwent reflection internally, and afterwards, as they emerged from it were again bent and brought on to the parallel line.

Fresnel, however, only conceived the idea of providing a fixed light in this manner, that is a light which shows all round the horizon, but Stevenson later made these prisms annular as well as cylindrical, and added them to Fresnel's lens panel so that they could help to strengthen the beam. Several of these panels were mounted on a table which was made to revolve by a clock, and thus either a series or a group of beams could be thrown to the horizon as the panels revolved to give single or multi-flashing characters for distinguishing one lighthouse from another.



FIG. 11.—Hyper-radial Lighting Apparatus.

These two principal developments formed the basis on which all modern optical apparatus now is designed, and the only improvements since those days are in the better manufacture of the glass and more perfect grinding and polishing of the faces to give accurate paths to the transient rays of light, which permits of panels of large dimensions being constructed.

These optical panels, with their framing, may weigh anything up to four tons, superimposed panels eight tons, and whereas formerly the table carrying them was supported on rollers which bore the whole of the weight, nowadays it is placed on a float running in a bath of mercury which helps it to ride more

easily, and enables a greater speed of rotation to be attained and the flashes to recur more quickly.

At Flamborough, where a quadruple flashing light was recently installed, the whole of the revolving portion of the apparatus makes one complete revolution every 15 seconds.

The intensity of the light depends upon the candle-power and size of the illuminating source and the arc of the panel, for all the several rays radiated from the source and impinging on the panel, instead of being dispersed as individual pencils of light over a wide angle, are collected and concentrated into one uni-directional beam, so that each one helps to intensify the other.

Theoretically, the candle-power of a beam is equal to the intrinsic brightness of the source of light per unit arc multiplied by the projected area of the panel, but owing to irregularities in the power of the burner and losses experienced as the rays pass through the glass of the optic and lantern, the practical value is about half the theoretical.

Illuminants for first-class lighthouses have passed through the various stages of coal and wood fires, candles and oil wick burning lamps to the modern petroleum vapour burner and electric filament lamp.

In the petroleum vapour burner, paraffin oil is forced under pressure into a vaporiser where it is heated and turned into vapour, whence it issues into a mixing chamber, where it forms with air a gas, to produce when lighted a bunsen flame, similar to the well-known "Primus" stove. The light is obtained by placing over the head of the burner an autoform mantle, which is illuminated by the heat of the flame. This mantle is formed of a silken fabric impregnated with rare earths, and when unburnt is soft in texture and can be handled indelicately. As soon as it is placed on the burner, however, it takes up on its own the correct spherical shape required for a source of light.

In a first-class light, such as the Eddystone biform, a candle-power of not less than 500,000 candles can be obtained with this type of illuminant.

Where higher powers are required, electricity is chosen for the illuminating source. Hitherto the arc lamp has been employed but the development of high power electric incandescent filament lamps has caused its supersession, and lamps up to three and four kilowatt are now installed at lighthouses. These have been combined with automatic electric equipment which permits of economies being realised, and where a local electric supply is available large savings to be effected.

At South Foreland, which has no fog signal, and which has been an electric light station for upwards of 60 years, there was once an arc lamp in the lens, with a large power-house and steam electric-generating plant for producing the current for the lamp, necessitating an engineer and four keepers, at a cost of £770 per year, to maintain the establishment. Now there is only one resident keeper, and he is able to have a complete night's rest instead of having to carry out the usual nocturnal duties pertaining to a high-power watched light.

To accomplish this great change, high tension electric cables were brought from Dover to the lighthouse, where the voltage was transformed down to the 80 volts required for the filament lamps. Despite the fact that the power of the light is over a million candles, the whole installation is automatic, the clock revolving the lens being wound up electrically at regular intervals, and a lamp changer being installed for automatically replacing a lamp when the filament of the one in service burns out, or for bringing a standby acetylene burner into focus if the electric current fails. This ingenious and labour-saving method of changing the lights was invented and perfected by Mr. John Poland Bowen, M.Inst.C.E., B.Sc., the engineer-in-chief of the Trinity House.

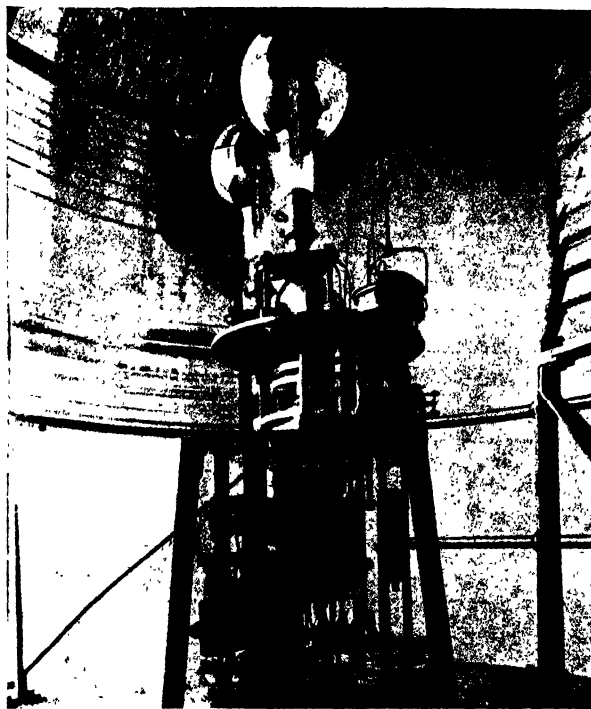


FIG. 12.—Automatic Electric-Acetylene Lamp Changer.

Although the keeper maintains no watch and need not remain in the lantern, he is kept advised of the running of the light by means of tell-tale devices. One of these shows a green light so long as the installation is working properly, while the other extinguishes the light and rings a loud-sounding gong if any derangement takes place.

A somewhat similar installation has been put into the Lizard lighthouse, which also has been electric for more than 50 years, but in this case the current is generated, *in situ*, so that personnel to run the machinery has to be

employed. An economy, however, of over £350 a year has been made, and the maintenance personnel reduced from an engineer and four keepers to a principal keeper with two assistants.

At other lighthouses, including Pendeen, Skerries and Hartland Point, where a high candle-power is deemed necessary, and in order to obviate a double watch being kept during fog, electric light has been introduced in place of the petroleum vapour burner system; while similar installations have been put on four new light vessels. In these cases, the electric power is generated *in situ* by small modern semi-diesel engines direct-coupled to the dynamos.

For secondary lights and buoy lighting, acetylene gas, burnt either as open flame or in conjunction with a mantle, is now generally adopted in the Trinity House service, except where electricity from a local supply is readily obtainable, an instance of the latter being at Burnham, where the two leading lights are being converted to take the incandescent filament lamps.

An interesting instance of acetylene gas employed with a mantle exists on No. 26 Light Vessel, marking the Barrow Deep Channel in the Thames estuary, where the lens is mounted on a table and made to revolve by the gas on its way to the burner before being consumed. The lens table is balanced on a pivot in the lantern and connected by three vertical pull-wires to another balance weight, placed in the hull of the ship at the load water line, which controls the movement of the upper table.

This forms a new departure for the suspension of dioptric apparatus on floating bodies, and as the motion imparted to the lower balance weight is small, the swinging of the lens table is less than with the older arrangement of pendulum and gimbal suspension.

FOG SIGNALS.

Fog signals are provided in three ways :—

- (1) by aerial fog signals ;
- (2) by submarine fog signals ; and
- (3) by wireless fog signals.

In the first group come whistles, bells, explosives, reeds, sirens, and diaphones, of which the last two are recognised as being the most efficient where first-class signals are required.

Both are compressed air instruments fitted with trumpets. The diaphone, the more powerful, consists of a piston reciprocating in a cylinder, around both of which are cut circumferential slots, or ports. The piston is fitted with an operating head to which air is admitted, first on one side and then on the other, for giving it the reciprocating motion. As the slots in the two units pass and repass one another air is admitted through them to produce the aerial sound, and the number of times these ports open and close each second gives the note. In the case of the siren the piston revolves in the

cylinder instead of having a to-and-fro motion, but otherwise the principles of air admission are the same.

A distinctive feature of the diaphone is the quick descending note termed the "grunt" at the end of each blast. This grunt can sometimes be heard when the remainder of the signal is inaudible, and so is of great value.

To provide the air for these instruments, compressing machinery, consisting of semi-diesel oil engines and compressors and large capacity air storage receivers, is provided, and two sirens with their axes approximately 120° apart horizontally are fitted for distributing the signal over a wide arc.

In recent diaphone installations at Hartland and Skerries the mouths of the two trumpets are placed on a common vertical axis with their centres half a wave length apart, to give effect to the theory propounded by Lord Rayleigh, that vertical dispersion of sound was by this means avoided.

CANDLES.

In the submarine group come bells, which are operated by compressed air, and oscillators, which are actuated electrically. The latter instrument comprises a vibrating diaphragm of large dimensions, but in principle of operation is similar to the working of a telephone. It sends out a high note, to which can be given a characteristic code, and the underwater range of the signal has been known to exceed 50 miles.

Wireless fog signals are of three types :

(1) A stationary wireless beacon transmitter from which a characteristic signal is sent out in all directions, so that it can be picked up by a ship fitted with a direction-finder or compass ;

(2) A rotating short-wave directional wireless beam transmitter, which sends out a different characteristic signal on all points of the compass as it revolves. These signals are received on board ship on a special aerial, and the special signal heard corresponds to the bearing of the ship with the station.

(3) A rotating wireless loop transmitter, which is made to revolve at a definite constant speed and sends out on North and East zero points a characteristic signal, followed during the remainder of the revolution by a continuous dash. The bearing in this case is taken by means of a stop-watch in conjunction with an ordinary wireless receiver, and is obtained by noting the time which elapses between the hearing of one or other of the zero point signals and the total extinction of the continuous dash. As the loop makes so many revolutions in a definite period, the determination of the bearing is merely a matter of computation between the speed of rotation and the time recorded by the stop-watch.

Each system has its merits, but the first, that is, the beacon station, is probably the most efficient of the three. It is comparatively cheap to instal, easy to maintain, and can be fitted either on shore or on board a light vessel. Moreover, this form of wireless fog signal necessitates a ship being fitted with

a direction finder, which is useful, not only for the purpose of obtaining a bearing of the beacon station, but also of enabling the ship to take bearings of other ships at sea during fog, or, as has frequently been proved with advantage, of a ship in distress.

Further, when the wireless signal is combined with an underwater signal and made to synchronize with it, distance from as well as bearing of the station can be obtained.

A typical beacon station has been established at Round Island in the Scilly Islands, and has been in operation for nearly nine months. The power of the transmitter is $\frac{1}{2}$ -kilowatt, and good bearings are obtainable from it at distances of 100 miles and over. The whole of the equipment is automatic, and is controlled by a master clock which starts up the plant and sends out the signals at the prescribed intervals to Greenwich mean time. Being automatic, little attention is required except for items of every-day maintenance, such as refuelling and cleaning, and it has been found practicable to run the station without addition to the present staff, who receive emoluments for the small extra duties imposed upon them. Four more similar stations are in course of erection at Caskets, Skerries, Start Point, and on Lundy Island.

FIG. 13.—Wireless Fog Signal Transmitter, Round Island Lighthouse.

A wireless fog signal of the second type has been installed at Inchkeith in the Firth of Forth, and though the receiving apparatus is simple, inexpensive and inelaborate, the transmitter has disadvantages in that the range is small and a large rotating structure is required for producing the beam. In addition, as the bearings must be given relative to a fixed zero, the system is inapplicable for use on a light vessel.

The third system may have its advantages in that the receiving apparatus is small and inexpensive, but the power employed is nearly twenty times that of the beacon for less range, while for the cost of one of these stations four beacon stations could be established. The cost of maintenance, too, is high

and will probably prove to be about ten times that of the beacon station, as a careful watch must be kept on the timing of the rotation of the loop, which means special keepers being always in attendance to look after both this and the large power plant. Experiments have shown that the transmitter is delicate and must be free from local interference if accuracy of bearing is to be assured, so that sites for this type of station have to be carefully selected. Like the second system, this one also is incapable of adaption for use on a floating body, because of the necessity of having fixed zero points.

One loop station has already been established experimentally at Gosport.

I should like to say that the Lighthouse Authorities mentioned in this paper are the General Lighthouse Authorities. The provision of Local Lights is efficiently carried out by the various Local Harbour Authorities. On the English and Welsh Coasts Local Lights are periodically inspected by the Elder Brethren and reports made to the Board of Trade.

There is very much more that I have been unable to tell you. As you will have seen, it is a large subject. I have told you nothing of the organization of districts, or of the constitution of our Service in its rank and file. Perhaps it is enough to say that the mariner is faithfully served by the vigilance of the officers and men of the Trinity House, whether in tenders, lightships, lighthouses and pilotage and buoyage work. Their devotion to duty is written plain in the safe navigation of the coasts of Great Britain; and that, I think, is the recognition they would wish to receive.

The Trinity House survives in its ancient form; but its pulse is steady and its heart is young. It is one of those truly British institutions that adapt themselves, not by revolution, but by evolution, to the advancing needs and knowledge of our country.

DISCUSSION.

THE CHAIRMAN, in opening the discussion, said he desired to propose a most hearty vote of thanks to Sir Arthur Clarke for his very instructive lecture, to which he had listened with the greatest possible interest. He felt as if he had been conducted over a lighthouse and shown everything pertaining to it, and that feeling was made stronger by the most artistically contrived smell, which still persisted. He was always fond of lectures where experiments were a part of the entertainment, but he could not say that he regretted that one experiment had been left out that evening; he had been told before coming into the lecture room that there was a fog-signal which would be audible 40 miles away. He was glad that had not been tried in that room. Sir Arthur had put forward the history of the very ancient Corporation of Trinity House in as abridged a form as possible. A few years previously, when he had had the honour to be elected a Younger Brother, he had tried very hard indeed to find any book or publication that would give the history of Trinity House, and he had not been able to find anything of the kind. There was a very small book, but it was most incomplete, and he was informed that his search would not be successful, because so many of the records had been burnt at the time of the Fire of London at Deptford, and therefore there was no reliable

book or publication to be got. The work of Trinity House didn't often come to the notice of people who were not sailors, though they found it to be a subject of very great interest when once it was brought before them. But English people were very prone to take everything for granted. The thing worked very well, and the ships came in and out without much trouble and with extraordinary punctuality, and therefore people did not think very much about it, or what means were employed to ensure that the channels were marked, and that pilots were available, and so on, to secure that punctuality in fine or foul weather, or worst of all, in fog. He hoped the effect of the paper might be that a good many more people might be prompted to take a deeper interest in very interesting subject.

The vote of thanks to the lecturer was carried unanimously.

SIR WILLIAM REARDON SMITH, Bart., recalled that it was in September, 1868, that he started going to sea. He was then cook of a sailing smack, and his first duty was to look after the side lights, not the shore lights, and his second duty was to peel the potatoes. He peeled them too thick, and the captain peeled them every day after that.

COMMANDER E. C. SHANKLAND (Port of London Authority) said that those who had to do with port administration were always very glad when they were under the wing of Trinity House. In London they were fortunate in that respect. Liverpool and Glasgow had to light their own waterways, and it was a very anxious time in winter during fog when the unwatched lights were out of the range of vision, and were not always functioning as one would wish, though they were getting more and more accurate every day. When one considered that the cost of lighting the coasts, viz., £1,000,000 per annum, was less than the cost of a single large mail and passenger boat, which might be £1,500,000 or more, he did not think that the cost of the lighting service appeared excessive.

MR. C. C. PATERSON, O.B.E., M.I.C.E., M.I.E.E., (General Electric Company) said it had been a great pleasure to listen to Sir Arthur Clarke's lecture, and particularly to see the very great advances that had been made in the automatic electric control of various devices and shore lights. It was gratifying to realise how reliable they were. It had been very interesting to him to see his old friend the lighthouse lamp again. He had had the pleasure the previous year of showing a larger edition of that lamp: one possessing about double its intensity, and although the lamp shown looked exceedingly large, it should be possible to get even greater power if necessary. As an electrical engineer, as a physicist, and as a yachtsman he had enjoyed the lecture enormously.

SIR ARTHUR CLARKE, in reply, said the question had been put to him just before the meeting as to why red and green lights were not used as well as white lights. The reason was that with a red light one lost nearly 60 per cent., and with a green light something like 72 per cent. of the candle-power. That was why red and green lights were not used by lighthouse authorities, except, of course, for small harbour lights, where the intensity was not of such great importance.

MAJOR SIR HUMPHREY LEGGETT, R.E., D.S.O., in proposing a vote of thanks to the Chairman, said that as everyone knew, Sir Richard Williams-Bulkeley occupied a very prominent position in one of our national sports, i.e., as Commodore of the Royal Yacht Squadron, and by his presence that evening had shown that a love of

sport went hand in hand with all those things which made for the greatness of England on the salt water. It was most appropriate that the lecture should have been held within 24 hours of the announcement that H.R.H., the Prince of Wales had been appointed by His Majesty the King to the headship of the British Mercantile Marine and Fishing Fleet. He was sure that Sir Arthur Clarke would feel that he could not have had a more appropriate night for telling them how the British mercantile marine had been served by the Trinity House. There was one regret that he felt, and that was that the Chairman and Sir Arthur had not come in their official uniform, for it was, he believed, something worth seeing. He knew that when one distinguished Elder Brother went to Belgium during the war, the Belgians asked what he was wearing, and were told in French that it was the uniform of the Elder Brethren of Trinity House. The Belgians still did not understand, and were told that the gentleman was a "Frère aîné de la Trinité," at which the Belgians exclaimed "Good heavens, what a position!"

The vote of thanks was carried unanimously and the proceedings then terminated.

NOTES ON BOOKS.

THE MANUFACTURE OF ARTIFICIAL SILK. By E. Wheeler, M.B.E., A.C.G.I., A.I.C. With a Foreword by Sir William J. Pope, K.B.E., D.Sc., LL.D., F.R.S. London: Chapman and Hall, Ltd. 12s. 6d. net.

Even to the man in the street artificial silk has recently become a matter of interest from more than one point of view; and the appearance of this monograph, the first of a series on applied chemistry under the editorship of Dr. E. Howard Tripp, is therefore singularly opportune.

The substance cellulose, like many other products of vital activity, is what is known to chemists as a colloidal "gel"; that is to say, it is in many respects comparable to a glue which has set hard. In its natural state it may be fibrous in texture, as in cotton, which is readily spun into threads and woven into fabrics; but most forms of cellulose, such as that in which it occurs in woody tissues, cannot be directly used in this way. Nevertheless, these forms are potentially useful, merely needing certain preliminary treatment.

The problem is essentially similar to that which confronts a carpenter who buys glue in hard sheets, which must ultimately be transformed into thin hard films in the joints of his woodwork; and it is solved in an analogous manner. Solid-seeming gels can be forced by suitable means to undergo a process of liquefaction, or more correctly "sol" formation. In the liquid or sol condition they will, of course, take on any shape that may be required, whether film or filament; and on re-conversion to the gel state they will retain that shape permanently as hard stable bodies. The carpenter's process for carrying out this transformation is a very simple one, because his glue gel has merely to be warmed with water in order to cause liquefaction to the sol state; and the latter by cooling and evaporation reverts to the hard gel, as is well known. Cellulose, however, is a more intractable gel, and needs a somewhat severe chemical treatment before it will take on the complementary sol condition.

Mr. Wheeler gives a very lucid and readable account of the four ways in which this reversible transformation of natural celluloses is effected commercially. These are: The viscose process, in which the cellulose is converted by means of carbon

bisulphide into a sulphur derivative which forms a sol with water; the cuprammonium process, in which the cellulose forms a complex compound sol with an ammoniacal solution of copper oxide; the nitro-cellulose process, in which nitrated cellulose forms a sol with ether-alcohol; and the acetate process, in which cellulose acetate forms a sol with acetone.

So far, the four methods are largely analogous, and the same applies to the spinning processes. In these, the liquid sol is forced through exceedingly fine holes into a bath of some liquid which has the power of re-converting it to the hard solid gel, which thus persists in the form of fine filaments. These last are immediately spun by appropriate machinery into a thread which is capable of being used for the weaving of any kind of fabric.

The sol, however, it will be remembered, was not a sol of cellulose itself, but of a complex cellulose compound; and the four processes differ considerably in regard to the regeneration of plain cellulose. In the viscose process, the compound breaks up at the moment of gel-formation, so that the thread consists of cellulose from the first; and the same seems to be true of the cuprammonium process, though the gel is contaminated with a good deal of copper, which has to be removed. In the other two processes, on the other hand, the spinning-bath merely coagulates the sol to a gel without altering its chemical composition; and we thus have a nitrocellulose thread which must be de-nitrated to plain cellulose by subsequent treatment; or a cellulose acetate thread from which the acetate groups never are removed, but which remains as cellulose acetate even in the finished product.

The author avoids as far as possible advertising particular firms, but one may gather that it is the viscose process that is used by Messrs. Courtaulds, the cuprammonium process by the Brysilka factory, the nitro-process by Bulmer Rayon, and, as well known, the acetate process by British Celanese.

After full and intelligible descriptions of these processes, the author passes to a consideration of the properties of the finished silk, and of the methods of dyeing. Chapters follow on the uses of the material, on the manufacture of some miscellaneous artificial cellulose fibres, and finally, on the economics of artificial silk production.

WIRELESS PRINCIPLES AND PRACTICE. By L. S. Palmer, M.Sc., Ph.D., A.M.I.E.E.
London: Longmans, Green & Co., Ltd., 1928. 18s. net.

The author of this book appears to have realised the need of a medium-size up-to-date text-book on the fundamental principles of wireless communications, suitable for the electrical engineer and the serious scientific experimenter. The book under review successfully meets that need as a complete course on the fundamental theoretical principles of wireless, illustrated throughout with practical examples and the results of much recent scientific research.

The subject is introduced by a chapter on wave-motion, followed by a study of wireless circuits and the properties of high-frequency alternating currents used for the generation of electro-magnetic waves. The all-important thermionic valve is discussed in several chapters, dealing with the theory of its operation and with its application as an oscillation generator in transmission, and also as a detector and amplifier in receiving circuits. Although the book is not intended to deal with the historical side of the subject, a chapter is suitably devoted to the Spark, Arc and Alternator methods of generating high-frequency alternating currents. A brief mathematical treatment of the electro-magnetic theory is given in a subsequent chapter, which also contains an account of various scientific investigations into the mode of propagation of wireless waves round the earth's surface, and of the

nature of atmospheric. This chapter shows that the author has kept himself abreast of modern scientific research, and some of the material presented is, we believe, published for the first time. The book concludes with two interesting chapters on Wireless Telephony and Directional Wireless respectively. The former is, perhaps, rather short in view of the modern developments of Broadcasting, but we are loth to criticise a successful attempt to compress a survey of such a wide subject as modern wireless communication between the covers of a single volume.

The book is well written, is remarkably free from misprints and is produced in an excellent manner at a moderate price. Although it contains a well-chosen proportion of mathematics, all the important formulæ are accompanied by interpretations and explanations, which will make them clear to the reader of limited mathematical attainments. The bibliography, which appears at the end of every chapter, is a useful feature of the book, and will enable the student to extend his reading in any direction he so desires.

R. L. SMITH ROSE.

THE SOIL AND CIVILISATION. A modern concept of the Historical Development of Agriculture. By Milton Whitney. London: Chapman and Hall, Ltd. 15s. net.

This work of nearly 300 pages is a volume in the American "Library of Modern Science," now being issued by Messrs. Chapman and Hall. The author makes the book interesting and discursive by ideas or metaphors derived from social or other parallels or aspects; the first chapter (pp. 1-48) commencing with thoughts and speculations on man as the operative force acting on the soil. As regards the soil itself we are told many things: among others the author tells us on p. 2 that "the soil is a living thing having many of the characteristics of an animal, and requiring the same kind of intelligent care as an animal to keep it in condition to give the most effective service." This notion runs through the book; for example, on p. 134 we have a comparison between "the bones of the living animal," and "the skeleton of the soil, the rock fragments," but much is left indefinite. On the next page (135) we read that "soil has a closed circulatory system such as the animal has—."

Another idea which is prominent on pp. 1 and 2, and also pervades the book, is that certain aspects of knowledge or experience may tend to disqualify for other work, one of the various examples being: "A man who has handled the Percheron draft horse should not be entrusted with the care and training of the thoroughbred race horse." Although much space is devoted to extreme specialisation as leading us to the evolution of efficient "soil scientists," the author admits that specialisation must not go too far, and he illustrates this in his quaint way by telling us that "it is not necessary to have one class of physicians for clerks, another for professional men, and another for musicians." (p. 13).

Notwithstanding the unusual views and confident dicta of the author, there is so much interesting and discursive matter in the volume as to make it attractive and useful, not only to the general reader but also to the more profound students of Plant Physiology and soil treatment.

QUALITATIVE ANALYSIS. By William Wardlaw, D.Sc., F.I.C., and Frederic William Pinkard, M.Sc., A.I.C., Lecturers in Chemistry in the University of Birmingham. London: Longmans, Green and Co., Ltd. 3s. 6d.

So many text-books on elementary inorganic qualitative analysis are in existence at the present time that it must be a matter of doubt whether the appearance of a new one is justified, unless it can offer some considerable originality of treatment.

A text-book on original lines might indeed be very welcome, for it is certain that the teaching of this subject is not in a very satisfactory state.

Probably the reason for this is that the traditional methods attempt to kill too many birds with one stone. Apart from its declared object and intention, practice in qualitative analysis is believed to perform a number of useful functions: it teaches students to exercise care in the minutiae of manipulation and observation; it depends on principles which are of great interest when properly explained and apprehended; it may afford excellent training in that rather elusive chemical *moral* which is so rarely appreciated in extra-chemical circles; and finally it is essential to the passing of examinations. The truth is that these diverse objects somewhat hinder one another; traditional procedures which further one will militate against others; and only too often the student will muddle through without having absorbed any of the desired characteristics.

Much might be said, then, for a break with tradition; but no such new departure is to be found in the present work, in which the general treatment follows the usual lines. It is good of its kind, however, and a real attempt is made by means of copious annotative matter to extricate students from many of the difficulties into which they are liable to fall. What is sometimes not easy to see is why these notes are not carried a little further. Warning is given, for example, that bismuth and antimony oxychlorides may possibly be produced as unexpected precipitates by the addition of hydrochloric acid at the beginning of the systematic wet examination for metals; but every experienced teacher has known students reduced to hopeless confusion by the appearance at this stage of quite a number of unpredicted precipitates, such as sulphur from a thiosulphate, hydrated silica from sodium silicate, or even barium chloride from a strong solution of that salt. One would have liked a little more assistance in such matters.

Good features of the book are a well-planned and informative solubility table for salts, and a list showing desirable laboratory concentrations for a number of common reagents.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, APRIL 16..Electrical Engineers, Institution of, Savoy Place, W.C. 7 p.m.
Transport, Institute of, at the Queen's Hotel, Birmingham. 6 p.m. Annual General Meeting.
Victoria Institute, at the Central Hall, Westminster, S.W. 4.30 p.m. Rev. Charles Boutflower, "Sennacherib's Invasion of Judah, 701 B.C."

TUESDAY, APRIL 17..Civil Engineers, Institution of, Great George Street, S.W. 6 p.m. "Sluices and Machinery of the Gezira Irrigation Scheme: Blue Nile Dam and Canalization." "The Gezira Irrigation Scheme: Canalization of the Gezira."
Petroleum Technologists, Institution of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 8 p.m.
Photographic Society, 35, Russell Square, W.C. 7 p.m. Meeting of the Scientific and Technical Group.
Statistical Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 5.15 p.m.
Transport, Institute of, at the Institution of Electrical Engineers, Savoy Place, W.C. 5.45 p.m. Mr. T. E. Batty, "Rolling Stock Problems."

WEDNESDAY, APRIL 18..Colonial Institute, at the Hotel Victoria, Northumberland Avenue, W.C. 8.30 p.m.
Fuel, Institute of, at Burlington House, W. 6 p.m.
Geological Society, at Burlington House, W. 5.30 p.m.
Historical Society, 22, Russell Square, W.C. 5 p.m.
Mme. Inna Lubimenko, "Russian Relations, 1642-1689."

Meteorological Society, 49, Cromwell Road, S.W. 5 p.m.
Metals, Institute of, at Thomas's Café, High Street, Swansea. 7 p.m. Annual General Meeting.
Transport, Institute of, at the Lime Street Station Hotel, Liverpool. 6.30 p.m. Mr. C. B. Nixon, "The Problems of Motor Transport."

THURSDAY, APRIL 19..Aeronautical Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 6.30 p.m.
Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m. Sir Oliver Lodge, "Recent Advances in Physics." (Kelvin Lecture.)
Linnean Society, Burlington House, W. 5 p.m.
Mechanical Engineers, Institution of, at the Town Hall, Bradford. 7.30 p.m. Prof. G. F. Charnock, "Mechanical Transmission of Power."
Photographic Society, 35, Russell Square, W.C. 7 p.m. Mr. T. F. Hollyer, "Some Aspects of Colour Printing."

FRIDAY, APRIL 20..Dyers and Colourists, at Manchester. Annual Meeting.
London Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 5 p.m. Mr. H. H. Dalrymple-Hay, "Some Features of Underground London."
Medical Officers of Health, Society of, 1, Upper Montague Street, W. 3 p.m. "Causes of the Decline in Tuberculosis Mortality." Speakers: Sir Robert W. Philip, Dr. W. M. Willoughby, Dr. E. L. Collis and Major Greenwood, F.R.C.P.
North East Coast Institution of Engineers and Ship-builders, Newcastle-upon-Tyne. 6 p.m.
Photographic Society, 35, Russell Square, W.C. 7 p.m. Meeting of the Pictorial Group.

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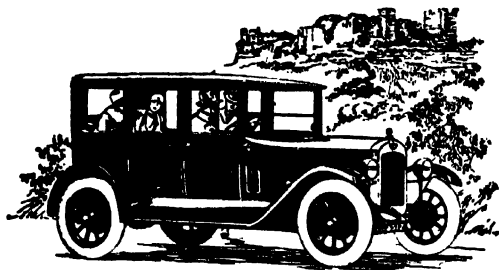
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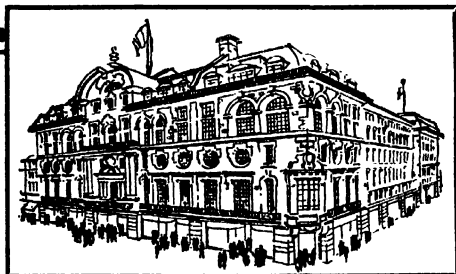
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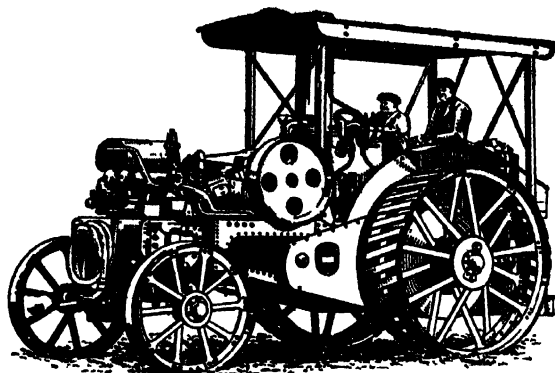
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FRIDAY, APRIL 20th, 1928.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK.

MONDAY, APRIL 23rd, at 8 p.m. (Dr Mann Lecture) A G HUNTLEY, of the May Construction Co, Ltd. "Applied Architectural Acoustics." (Lecture II.)

WEDNESDAY, APRIL 25th, at 8 p.m. (Ordinary Meeting) J M RICHIE, M.A., Ph.D., "The Education and Training of the Blind" CAPTAIN SIR BEACHCROFT TOWSE, V.C., K.C.V.O., C B E., Chairman of the National Institute for the Blind, will preside.

DR. MANN LECTURE.

MONDAY, APRIL 16th, 1928. MR MAURICE E. WEBB, D.S.O, M.C., F.R.I.B.A., in the Chair. MR. A. G HUNTLEY, of the May Construction Co., Ltd., delivered the first of his course of three lectures on "Applied Architectural Acoustics." The lectures will be published in the *Journal* during the summer recess.

EIGHTEENTH ORDINARY MEETING.

WEDNESDAY, APRIL 18th, 1928. PROFESSOR A. E. RICHARDSON, F.R.I.B.A., Professor of Architecture, University College, London, in the Chair.

A paper on "American Architecture" was read by MR. ALFRED C. BOSSOM, F.R.I.B.A. The paper and discussion will be published in the *Journal* dated June 8th.

COMPETITION OF INDUSTRIAL DESIGNS.

By kind permission of the Board of Governors of the Imperial Institute, the public exhibition of works sent in for this year's Competition of Industrial Designs will be held in the Exhibition Pavilion of the Imperial Institute,

South Kensington, S.W. Full particulars of the Scholarships and prizes offered in connexion with the Competition can be obtained from the Secretary of the Royal Society of Arts, Adelphi, W.C.2. Applications for forms of entry, labels, and instructions must be sent to the Secretary of the Society between May 1st and May 12th. The designs entered for the Competition are to be forwarded to the Imperial College of Science and Technology, Imperial Institute Road, South Kensington, S.W., between June 18th and June 20th, and after the judging, which takes place in July, the accepted designs will be exhibited at the Imperial Institute from August 4th to September 1st (Sundays included).

PROCEEDINGS OF THE SOCIETY.

FOURTEENTH ORDINARY MEETING.

WEDNESDAY, FEBRUARY 29TH, 1928.

THE RIGHT HON. GEORGE N. BARNES, P.C., C.H., in the Chair.

THE CHAIRMAN said that Mr. Archibald Crawford was the son of a worthy father, who left a very fine record of social service in the industrial city of Glasgow. Mr. Crawford had followed in his father's footsteps, but circumstances had called him to a wider field. Like many Scotsmen before him, he had been lured to London, and he had forsaken law for the directorship of the Economic League. The speaker knew nothing of the Economic League, but he noted that the list of its supporters included some well-known industrialists and pioneers of social thought, such as Sir Robert Hadfield and others of like mind. But in any case, economic science had a bearing upon the subject matter which would engage the attention of the Society that evening, and he was sure that Mr. Crawford was well qualified to speak by virtue of early associations as well as later experience.

The topic was "Industry Fifty Years Hence." Mr. Crawford with much daring was going to assume the role of prophet, and, the speaker supposed, the role of historian as well, because, after all, the gift of prophecy depended to a large extent on the knowledge of what had been and why it had been. In that sense the record of the last fifty years was germane to the forecast of the next fifty. It so happened that he (the speaker) could look back over the whole of that period, and more. Fifty years ago he was working with a firm of engineers, and ever since then he had been in fairly close touch with industry. He had seen many industrial changes, some of which in their developments had a very important bearing upon what was still to come, and on two of these developments—machinery and organisation—he would like to make a few observations.

He thought it would be a matter of common agreement that the main change in industry in their time had been the increasing use and improvement of machinery. We were living in an age that might be said to be mechanical. The old type of mechanic was fast dying out, and was being replaced by the machine-tender. What was going to be the effect of that upon the labourer and upon the community? There was one thing, he thought, increasingly obvious—namely, that the worker

did not like the change. Increased wages and reduced hours of labour had failed to produce industrial harmony. That was one of the paradoxes of industry at the present time. The reason was fairly clear. It was that the individual—the workman—was now less important than he used to be. He was being specialized, and simplified, and kept in a groove; the going concern was regarded as the workshop or the plant, and the manual worker was simply used according to the needs of the mechanical process. The speaker suggested that this was having a bad effect upon the mentality of labour and upon the community generally. The simplification of processes was coming about at a time when the worker was called upon to a larger extent than ever before to control national policy. This new mentality was reflected in jazz bands and sex films, and plays, and in ready-made excitement, which to his mind was bad; and if these things were the result of the cramping effect of industry upon character, then they had a bearing upon the next fifty years. He quoted some words from an American writer in a book recently published concerning the limiting of talents, physical and spiritual, native to the race as a consequence of machine technology, and added that to his mind men would not stand this unless they became something less than men. He believed that in some way or other the ordinary workman in industry must find his self-expression in his work or, on the other hand, must live away from his work. The first of these alternatives, it seemed to him, was very difficult unless the average workman were to be trained in two or three specialised functions and allowed to take them in turn, which would be almost impossible. If that could not be done then it was necessary to fall back upon the second alternative, which meant that the workman must yoke his will to his work and really make machines more productive—much more productive—than they were to-day, so that his hours of labour might be shortened proportionately. But this could not be brought about until the worker was in some way or other taken into partnership and given a share in results as well as in control. This meant quite a new conception of industrial relations, but boiled down it came to this, that both employers and workmen must regard themselves not as warring elements, but as servants of the community.

This brought the speaker to his other point, that of organisation. Fifty years ago there was little or no organisation. Every man was on his own. Now the individual, whether employer or employed, had to conform to certain rules and regulations imposed upon him by his union or his association, or whatever it might be. That, to his mind, had its dangers, because the condition of keeping our place in the world's markets depended upon producing goods at a price, and there was a risk of combines raising prices for their own interests. This might be done in collusion with the workmen; it had been done before, and it might for anything he knew be done now. But that was the danger, namely, the raising of prices, putting us to a disadvantage in world competition.

At present, apart from that, and in the main, workmen's organisations and employers' organisations confronted one another organised for combat, and sometimes breaking out into open war. He submitted that this could not last. Italy had called a halt. The strike and the lock-out there had been abolished, and arbitration had been made compulsory. That ran counter to British ideas of democracy. He would not say that Italy had gone the right way about the business, but he did think that something would have to be done to bring the organised community as a whole into some organic relationship with workmen's organisations, and the organisations of employers as well, so as to get the industry on an efficient footing. In itself organisation was a good thing; it was at least one remove from anarchy, it gave the opportunity for co-operation between employers and workmen and a chance of settling down and discussing their differences, and coming to something

in the nature of an agreement by hammering out their difficulties on the anvil of commonsense. That was the road to industrial efficiency and harmony, always provided that those who were so meeting met together with the idea in their mind of the interdependence of industry, and with the further knowledge that the State or the community as a whole was in the background to see fair play.

From a *précis* prepared by Mr. Crawford he gathered that he, on the other hand, thought that industry was going to settle all its own differences, and that it was going, altogether apart from politicians or outsiders of any sort or description, to do something to raise the conditions of labour and of life generally. The speaker could only say that he wished he could think that was possible. Mr. Crawford, so far as he understood him, conceived industry as a unit. Industry was not a unit. Industry was a congeries of interests, and it would only be in proportion as industry got away from that idea of sectionalism and regarded itself as the servant of the community, and pushed its own cart always in accordance with the goodwill and interest of the community, that the ideal which Mr. Crawford was about to envisage would be reached.

The following paper was then read:—

INDUSTRY FIFTY YEARS HENCE.

By ARCHIBALD CRAWFORD, K.C.,

Director of the Economic League.

Before I enter upon what seems likely to be, after the Chairman's opening remarks, a controversial discussion—to which lawyers are perfectly hardened—I would like to say that it is one of the proudest moments of my life to have Mr. Barnes in the chair this evening. I have not got quite fifty years' experience behind me, but all through such experience as I have had I have thought of him and admired his work, and when I asked him, greatly daring, to be my Chairman, I was very glad indeed when he willingly acquiesced. Therefore, between the two of us, the one who has been in industry all his life, and the other who is an outside observer of it, the harmonious relations of which he has spoken have already begun.

Mr. Barnes has, however, struck a note that would indicate some little opposition to what I propose to set before you. He has founded his opposition upon the *précis* I handed him. I have never given a *précis* before, and really I did not quite know how to construct it, so that Mr. Barnes may quite well have misunderstood what I intended to convey, and I will now do my best to put my ideas before you and will guarantee that Mr. Barnes and I will not be quite so far apart at the end as this little skirmish might have suggested.

I chose my title with some deliberation and perhaps cunning. The cunning consisted in choosing a period—fifty years—after which very few of those present would be able to confront me and to prove that I was wrong! This enables me to enter a little into the realms of speculation and to indulge my fancy.

Mr. Barnes has rightly said that in order to go into the future one must go also into the past. I agree, and I propose to do so to some extent ; but before doing so may I add just this remark, that I took the subject of the future of industry because I think that too little regard is paid nowadays to general ideas and too much to particular ones. I have met a good many people in industry and a large proportion of them appeared, perhaps naturally, to be more interested in the details of their work than in its direction and tendency. It is true that none of us actually know where we are going, yet by dipping into the past we may arrive at some general principles and get a little understanding on the subject of the future.

The mechanical advance of industry, involving to some extent the cramping of the soul of the worker, has been referred to by Mr. Barnes, and he has related this soul-cramping to the resort to the cinema and to jazz as the inevitable reaction. But does he think that the cinema and the jazz band are patronised only by those who in their daily work have merely to tend machines ? I fear that there are more " jazzists " and devotees of the cinema among those who do not have to tend machines than among those who do. Nevertheless I do think that one of the great dangers of the future is that with an ever-increasing mass-production in industry and an ever-increasing cutting in prices, workers in industry may become more and more mechanical ; processes which were formerly carried through from beginning to end by one man will be more and more distributed among several men, each concerned with his own narrow task, and we have to consider how the spiritually deadening effect of all this can best be countered. We are face to face with increasing mechanisation, and I cannot see how any reversion to the old guild industries or cottage industries could help the situation.

Industry has been described even to-night, and, of course, on countless other occasions, as a series of elements apparently at war with one another. Those elements I regard as four in number. In the first place, there is capital, which is the saving from yesterday—something which was not used yesterday and can be put into industry to-day in order to enable it to create something more. The second is invention, the ideas of the clever brain, the most important, I think, of all the elements, because without invention we should be in industry to-day where the world was thousands of years ago. Invention seems to me to furnish the key to the problem, and I concentrate on that brain element as one of the great factors in civilisation. The third factor is management, the one around which a great deal of discussion is taking place just at present, and in regard to which I foresee very extensive and widespread developments. The fourth element is known as labour, the work of those who tend the machines or who do the manual labour, and who form by far the largest element in this four-sided partnership.

For it is a partnership, even though some of the elements may be warring with others. A marriage is similarly a partnership, even though man and

wife do not always agree. This partnership is the means whereby all the material things in this world are created. In the past there has been friction, but, obviously, there is something here which ought to possess essential elements of unity. Inherently it is a partnership. Great developments have already occurred through the fostering of this partnership spirit. Let us go back a little into history. We all remember how a Scotsman once saw some steam coming out of a kettle and thereupon had a great vision of a revolution in industry as the result of steam power. Then came the mechanical and industrial revolution, during which there was released for the use of the world this great steam power. Even in these very beginnings we see the four factors I have mentioned coming into active co-operation.

So we come down to the great mass production of to-day. I affirm that industry has absolutely delivered the goods. Sir Josiah Stamp has pointed out that since 1800 the standard of life has been raised four times on a population which has increased five times. Therefore, we may claim that industry in carrying out that four-fold partnership has done some very good things for the world at large. It has had its defects, of course. These four elements in the partnership were thrown hurriedly together, and it may have been that capital and management, intoxicated by the power given to them, disregarded the fact that this was a partnership with labour and that it was human material they were employing. The result of that neglect was that we had a state of matters in the early days of modern industry which was a disgrace.

Thus there was a bad beginning, against which there came an inevitable reaction. Movements of a hostile character made their appearance, and those movements have been growing in impetus right down the century or so until now. They have had varying means of expression, at times political, and at other times industrial, their leaders now talking of direct action and now of nationalisation. But the effect has been to create a mental schism. Right from the start there began to be two minds in industry, and it is perfectly clear that you cannot have a successful partnership in which there are two minds. This state of affairs, however, as the century wore on, gradually ameliorated. Various ill-conditions were altered. There came about improvements on all the social sides of the relationship. The working man's condition was bettered as time went on and the productivity of the machine increased. Running through this partnership there was a spirit—a very elusive but yet essential feature—of free enterprise and initiative. It is a spirit which we in Scotland know a good deal about, but which is implanted in the British race as a whole, and the denial of which makes us into slaves.

As time goes on, then, we find what I may call the relationship side steadily improving in spite of constant efforts to disturb it. If we could invent some kind of machine which would photograph a colour indicating relationship value we should find on comparing the results at intervals of, say, twenty

years from 1830 down to the present time, that the colour was gradually improving, gradually becoming brighter and less lurid. At the present time, although there is a vast amount of opposition and contradiction in the industrial mind, the situation is enormously better than it used to be.

Thus we have up to the present date a machine which possesses the creative spirit, which has delivered the goods, and which, although it has encountered great difficulties, has achieved a constant amelioration of them. That is a broad picture of the past. We had in 1926 a final explosion which seems to have done more good in preparing the way for the future than anything else. Psychologists know that a person may have a "complex" which has a disturbing effect on health. If you brood over an idea both your bodily health and your mental outlook will suffer. But if you have some kind of explosion—if you are able to "have it out"—there is a clearing of the air and a great relief. I regard the General Strike and its consequences as a vast clearing of the air, and I think that to-day, to take the illustration I just mentioned, if another photograph were taken of the industrial atmosphere, we should find the situation very much brighter than at any previous time since the industrial revolution. A sign of this is to be observed in the conferences now pending between industrial leaders. These conferences make such a subject as we have before us this evening all the more important.

I have said that things have improved from the human relationship point of view during the last century, but as Mr. Barnes in his opening speech limited himself to fifty years back, I might indicate to you some of the things in respect to which during those fifty years there have been marked improvements. Every one of those improvements is a nail in the coffin of industrial unrest. Every one of them is a step towards industrial unity. Of course, the unity that we have got to create is a unity between two minds—perhaps two warring minds—the mind on the one hand of the employer or manager and on the other hand of the worker. In these last fifty years many things have been done, partly by the State, partly by employers, partly as a result of education and of agitation and partly as a result of greater enlightenment. In the first place, there has been Workmen's Compensation, which has made the position much better than it used to be from the point of view of those who have suffered injury and disablement. Then there have been insurance schemes both against sickness and unemployment, making a vast difference to those who are haunted by the fear of being out of work. Trade boards have been set up in regard to all the industries in which there were not large unions and large confederations of employers facing one another and discussing matters in a regularised way. During the last fifty years the Trade Unions have come into their own and have progressively gained in strength. So far as the worker is concerned he now has a very powerful spokesman in any of his difficulties. It may seem that that indicates a tendency more warlike than anything else, but I am not sure that as time goes on this machine which

possibly came into being for combative purposes, may not be utilised rather for peaceful purposes, and, indeed, there are already indications that this is happening. Conciliation machinery, again, has been set up, and the Printing Trade affords a very striking example of the success of conciliation. In the Steel and Iron industries, as well as in Cotton, and in Boots and Shoes, conciliation machinery has done an enormous amount of good.

In the early days the worker was isolated and defenceless; this can no longer be said, thanks to the defensive machine which has been set up on his behalf. Then there is another institution which appeals to me—namely, the Industrial Court. In some countries, it is true, compulsory arbitration is resorted to, a court being constituted for that purpose. But we in this country are a democratic people and do not like to be compelled in these matters. But the Industrial Court is already doing a good work. One of its difficulties is that it has no body of principle behind it, but then the same was true of our law courts in ancient times. The law courts at the beginning could have only actual facts in front of them, and gradually there was built up a body of law.

Now I come to the question of remuneration. So far as remuneration is concerned, we have seen a beginning of profit-sharing and the beginning of a thing to which I am much attached—namely, the holding by the workers of shares in the companies. There is also beginning a movement which deserves a great deal of attention, that of acquainting the worker with what is going forward in his industry as a whole. Again, there is better management than ever before. If people suggest to you that on going about the country you would see industry as a black abyss, containing nothing but warring elements, I ask you in return to go round some of our industrial centres and find out the actual conditions for yourselves. You will be astonished to discover what splendid relations exist in practice, and that the picture is certainly much brighter than the recital of some facts would lead one to suppose.

Another thing we have to remember is the improvement in the health conditions of the worker, partly, of course, as a result of State and Municipal activity, and again in consequence of the enormously improved safety devices for preventing accidents or illness at works. So that altogether we can say that after a bad start we have come to a point at which industry to-day, its whole psychology altered by the General Strike, is in a more hopeful condition from this point of view than it has ever been. The grave menace of unemployment is forcing men, instead of seeking another system, to see how they can get this system right, and by what practical expedients order and prosperity can be brought about. That is the good side of the picture as we have it to-day.

I should like now to point out some of the defects as I see them in the present position. There are certain overwhelming evidences that all is not well with

industry so far as relationships are concerned. We have the estimation of Mr. Rowntree that 200 million working days were lost in the last five years as a result of strikes and lock-outs. That is the first debit entry in the account. There were also lost—this must have been a very difficult figure to arrive at—200 million working days as a result of a failure in co-operation in industry. That is a serious state of matters, but I would point out to you two things which are even more striking instances of defect. In 1924 a total of twenty-eight million weeks were lost to industry because of bad health. There we touch a matter which possibly goes right to the root of the whole problem. Again, 58 million weeks were lost in 1924 as a result of want of work. Thus, on a comparative computation of losses, we arrive at the conclusion that if we were to tackle the question of health and the question of getting orders we should go very far towards having dealt with the primary problems on the side of industrial relationship. I am convinced that a good deal of the want of co-operation is due to lack of balance of mind through lack of balance of body. But most important of all is this festering sore of unemployment right at the centre of the national life. What we are going to do with it is another matter.

Another difficulty in the present situation is want of faith in the system of industry. It seems to me essential that if we are going to prosper in industry those on both sides of the partnership must believe that the kind of thing they are working at is the right kind. Therefore, any means that can be taken to create a belief that the system of private enterprise is the right system—I hope that everybody here does not agree with that, so that we may have a good discussion on the point later—should certainly be taken, for until that distrust is removed it will not be possible to wipe out the millions of days which are lost to industry by lack of co-operation and their failure in the spirit of partnership on both sides.

At the present time the worker is very much troubled because of insecurity and want of work on the one hand, and fear that the job he has got may terminate on the other. The best workers in this country believe that it is better to be at work than to be hanging about on the dole. The fear of unemployment is a cause of great disquietude and is exceedingly disturbing to the industrial partnership at which we are aiming. The workers complain also that in spite of Factory Acts and many excellent devices there is still a want of sufficient safety in many departments of industry. It will be agreed that the State has been very vigilant and active in regard to this matter, but the worker must also agree that when so many days were lost in ill-health not enough is being done for him to make him an efficient health unit in industry. The worker also feels that he does not know quite enough of what is going on. He may well feel that he would like to have a bigger conception of his work and the part which his particular job plays in the industry. He sees only the machine, and he does not feel quite satisfied. Again, the State, for

reasons no doubt sufficient in its eyes, has placed far too heavy a hand upon industry and is cramping it very severely, particularly in view of the forces which it has to meet in foreign competition.

I have told you of the bad beginnings, the gradual ameliorations, and the defects which still exist. I have also tried to state to you the necessity for the conception of industry as a partnership. Any other system which would divorce the four essential elements—capital, invention, management, and labour—is to be deprecated. The question is, how will they best work together in a free and cordial co-operation?

So much to prepare the ground for the Wellsian side of my picture. What is to be done in the future? I have taken the period of fifty years only as a useful period, sufficiently long to enable real changes to be brought about. If, thinking of industry as a unit, I might describe what appears to me to be its chief trouble at the present time, it would be that it is not self-conscious enough, does not sufficiently regard itself as a unit, and has allowed the State to come in and do for it what it ought to have done itself. Further, in allowing the Trade Union movement—to which I am not at all hostile, but quite the contrary—to have been created, it made a confession, in a sense, of bad management. That is not to be wondered at, because the thing was then only still in its beginnings; but if Henry Ford had been in charge at the beginning of the industrial revolution there might not have been any need for Trade Unions. But what industry must have is a self-conscious personality. In fifty years' time we shall find industry with a great brain centre, regarding itself as a unit, and keeping politicians in their places. Industry has great possibilities if it realises itself and understands all its difficulties. It can surely do its job for itself immensely better than people who have a bias in the direction of getting votes. If Industry is not yet capable of facing the thing by itself it certainly will be capable of doing so in fifty years' time, when it will have noted fully the harm of constant State interference.

Another thing which Industry will do will be to create a centre for research in all directions, for example, in respect to markets and inventions. Every kind of angle which may be helpful will be explored. Instead of a number of unrelated bodies groping their way, there will be an enormous industrial centre where the best brains in industry will be operating. The problems of finance—which, according to Sir Josiah Stamp, contribute more to the employment problem than anything else—will be matters for complete scientific research and ascertainment, not only in relation to one particular country, but to the whole world. There will be a complete publication of all the facts regarding Industry so that all the world may know what those facts are. There will be available a knowledge as complete as we can expect of the possibilities of production in one particular place and of marketing in another. We have an institution at present known as the Empire Marketing Board, which is beginning to work in that direction. Altogether, we shall

be able to rely on having a real brain centre for industry which, by its very excellence, will make politicians afraid to attempt to interfere any more than is absolutely necessary.

So far as relationships are concerned, there will be a new endeavour made to look after the interests of the worker outside the workshop itself. For example, housing undertaken by employers will increase to such an extent and there will be such a vast extension of privately owned houses as to make for ever unnecessary the State Housing Schemes which are being carried out at the present time. The matter of health will be thoroughly investigated. It is a perfect scandal that in a civilised country twenty-eight million weeks should be lost in a year because people are not well enough to go to their job. This will mean a recasting of the whole conception of the medical profession. It will be seen to be the function of the doctor, not merely to get his patient well when he is sick, but to keep him well and to protect him from sickness. Industry, even if the State itself does not insist on it, will see that its workers are kept in health. All these things are partially in operation at the present moment. In some cases the health and the housing of the workers are looked after. Again, many firms arrange pensions for their employees at retiring age; this will become more general. The security and the status of the worker will be much improved because management will have become a science. The whole of the staff will be dealt with on a properly graded scheme, and there will not be the same difference between the black coat and the overall as there is at present. A new solidarity between the workers of whatever grade will thus be achieved.

Management—in itself a most important thing—will be on a thoroughly scientific basis. A qualification will be required from those entering upon management. It is deplorable that there should have been hitherto so largely an absence of scientific training among those who assume control of vast numbers of people and of a vast amount of raw material. That all this should have been done in so haphazard a way is a matter for astonishment, but before many years are over the question of management will be tackled in a scientific fashion as well as in a human spirit, and when that is done all this talk about labour unrest will begin to disappear. It is the mishandling of people which is largely at the source of the trouble. The worker is not discontented because he is not at the top of the job; all that he wants is a sense of security and proper dealing, and if the management takes a grip of the situation in the right way a good deal of the self-defence "complex" from which the worker is suffering will begin to disappear.

I come next to the question of the increasing use of machinery. That is a very grave difficulty. It seems to me that unless the worker can get a picture of the whole of the task, from the raw material to the selling and to the service of the community, he is not likely to bring to bear upon the subject the interest which is so desirable. It is true that some people are quite satisfied with routine

tasks, but there are a great many others who are easily made discontented if they are unable to see anything outside the narrow groove of their particular job. Recently in Germany I witnessed an interesting experiment known as the "Dinta," in which eighty factories in the Ruhr and elsewhere are participating. Here the apprentices are trained first in their actual work and secondly in the relation of that work to the whole of the process from beginning to end. They are also given instruction in all kinds of social achievement; their health is looked after, and a hundred and one other things are done to give them a fuller idea of life.

So far as remuneration is concerned, I think that in fifty years' time the difference between capital and labour will have disappeared, because most workers will be capitalists and will have acquired shares in their own concerns. A Scottish employer told me the other day of the excellent results he had obtained by giving his workers debentures at $7\frac{1}{2}$ per cent. They had to purchase these for themselves. When it came to the ordinary shares, for every 2 per cent. given to the ordinary shareholder, 1 per cent. was given to the debenture holder. He said that the difference in quality of output since this scheme was started had been very striking. This share giving scheme, though operating fairly freely in America, is operating less freely in this country. After all, it is the divorcement of capital from labour that is causing much of the trouble. The proper state for these two parties is the married state. If the worker is enabled to become a shareholder a great many of the troubles will disappear, but, quite apart from that, there will be established machinery for seeing that wage conditions are absolutely beyond complaint. There will be an established minimum plus a standard dependent upon the ability of the worker, and to this will be added a profit-sharing scheme which will enable the worker to have a thorough understanding of the business. Above all, the worker will have the advantage of seeing the complete publication of all that goes on and therefore he will realise that he is part of a great service.

With regard to the Trade Unions, these will have had the ground cut from under their feet so far as their combative functions are concerned, but they will probably exist as machinery for stimulating interest in the work, for the purchase of shares and for increasingly large benevolent projects. But I think the conciliation machinery, which they have helped to create, will itself have become so far advanced that the idea of a trade union as a combative body will have disappeared. The industrial court will have received such support that it will be a means of settling disputes not settled by the internal conciliation machinery of the industry itself.

As for the State, I have left this out in the cold. I think you will find that as time goes on there will be less interference simply because we are actually at the beginning of an age—of which we have a foretaste in the conferences led by Sir Alfred Mond—when both sides will have become self-conscious, and the more they do for the industry which is their common interest, the

less will the State have to do. With these sign-posts erected by the State—in the shape of the conciliation boards—and the new consciousness in industry itself, the State will not be called upon to interfere.

Those, broadly speaking, are my rough ideas of what may be in operation in about fifty years' time.

DISCUSSION.

MR. W. A. APPLETON, C.B.E., (Secretary, General Federation of Trade Unions) agreed with Mr. Crawford that there should be a partnership between all the various factors involved in industry. He believed in the inevitability of that partnership, and had said so frequently, to the annoyance of some of his friends. The partnership up to now had often been upset and disarranged, just as the partnership between man and wife might be upset, especially if they lived near their relations. The industrial movement had lived too near to people who had claimed relationship with it. Industry, or the manual side of it, had felt that it was being unfairly dealt with, and the result had been an exaggerated desire to get rid of the economic system under which industry operated, in the belief that this must happen before anything could be done.

Well, the system of industry was an ancient one, and so far as one could see, it would be here for a good many thousands of years longer. It seemed stupid to put off doing what could be done to-day on account of something that might happen an indefinite length of time ahead. Ten or twelve years ago, at a meeting of the Copartnership Association, he had envisaged the possibility of the trade unions being superseded by something better. He had always been prepared to see the supersession of any institution by an improved one. He realised to the full that there was no force, other than Christianity, that had done so much for the average man as the trade union movement; but the movement had sometimes forgotten how far it was wise to go. To-day it was easier than a little time ago to persuade the average workman as to the necessity of this partnership.

It was said that scientific management was going to settle many difficulties. He believed that scientific management would do much, but it would never remove the necessity for sheer work, without which, indeed, it would be a lost kind of world for us all. There was no satisfaction so great as that of creating something through labour.

Lately he had been studying the problem of unemployment. He had, on occasion, said things with regard to that matter which were resented, but a better spirit was developing. Three weeks ago he spoke in Macclesfield to a crowd of weavers, he talked nothing but sheer business and economics, and he was cheered to the echo by people who were just ordinary working people. Unfortunately, it too often happened that in industry as in politics the man with the biggest voice was listened to, not the man with the biggest brain, who thought most deeply for himself, his fellows, and his country. But there were signs that men were increasingly appreciative of the logic of the economic situation.

SIR ARTHUR HOLBROOK, K.B.E., M.P., said that he had been greatly interested in the paper. He knew that the day had arrived when the workers were realising the fact that their share in industry must be larger than it had been in the past. At the same time, while that fact was accepted, the workers must also realise their

greater responsibility. If that could be brought home, the future would be easier for the progress of industry.

He agreed with Mr. Appleton that trade unions had had an enormous effect in improving the standard of life and the conditions of work. Up to a point no one connected with industry could ever oppose trade unions founded on sound principles. But latterly one's faith had been somewhat shaken by the fact that trade unions seemed to apply themselves almost entirely to political rather than industrial work. He would be sorry to see trade unionism superseded by any other organisation, but he felt that trade unions founded on the basis of improving the condition of the workers and raising their standard of life and getting them better conditions would have a greater effect if they reserved themselves for these functions, and he believed that their leaders were realising that fact. Mr. Crawford had hit the nail on the head by pointing out that the various elements in industry must work together. There were capital, management, and labour, and no two of them would be of any use without the other. When this was realised there would be greater success for industry.

He was not one of those who took a pessimistic view of the future. Some public speakers suggested that the days of England were over; he could not agree. The standard of English work was higher than it had ever been, and although British goods might be squeezed out of the markets of Europe because of their inability to compete in prices, yet everybody knew which was the best market to go to, and that was the British market. We had been too far behind—though this was less evidently the case to-day—in technical education. That had been our weakness in the past, but it was being remedied by the technical colleges established in industrial centres, of which he was astonished that a larger number of young men did not take advantage. It could not be said that any party had been niggardly in this provision. The Society of Arts had got a great system for encouraging competition and improvement in these methods, and if anyone was interested he would suggest that he write the Secretary and get from him a prospectus of the various competition schemes offered by the Society. Much was being done in this way to encourage progress in industry. He appealed for new members of the Society; to join the Society would be one means of assisting in the progress of industrial science and art in this country.

MR. W. MUNDY (Secretary, Industrial Co-partnership Association) said that Mr. Crawford in speculating on the future of industry had kept his feet on the ground. In the speaker's Association they dreamed dreams. He had been, nevertheless, extremely interested, although he had to offer some slight criticism. A great deal of the trouble between employers and employed in industry had arisen over the use of the word "capital" when the speaker intended to refer to the function of management. Mr. Appleton had just told them that he went to Macclesfield and preached a definite economic and was cheered. Quite so; the majority of workers were people who had thought and who knew absolutely well that there had to be capital to run any industry at all. Round about Northampton and Leicester, for instance, the workers not only knew what capital was, but tried to collect it for the running of their own industry. They had no objection to capital; their objection was to the feeling that the man who owned capital was getting too good a thing out of it and taking away from them and from industry something which ought to remain.

Too much was said about the identity of interest as between capital and labour. If there was an identity of interest there would be no quarrel. They were not identical, though it was the part of good management to find as many points of identity as possible. One of the points of identity that might be made was to

show to the worker that he was in partnership right up to the profit. The man then felt that he was given a square deal. The thing to go for at the present moment was to get every worker in the country to feel that he had freedom in industry, that he had a part to play in industrial citizenship, a part recognised by the management and by the general public, that he was not merely doing a job, but was working for the nation, and that it was worth bringing to his work all the capability that he possessed.

Had industry ever really gone out to the worker with both hands in this spirit? He would suggest to Mr. Crawford that that was the key to the new era of which he had spoken. The attitude of the worker to-day might appear to be that of one making a demand for more shillings or shorter hours, but what he really wanted was a hope for his own life and his children's lives. He wanted to see something better on the horizon. He wanted the garden city, and to be rid of a great deal of South London, and West Birmingham, and South Leeds. How could one talk about citizenship in some of those places? What sort of people did one expect from some parts of Wolverhampton, and Dudley, and Walsall? Through profit-sharing, through citizenship in industry, from the works council—with which the trade union would have to work—there might be gradually evolved a new state of industry wherein the worker, rejoicing in a more humane environment, would be conscious of making his contribution to the common good.

SIR ARTHUR W. CLARKE, K.B.E., said that there was one question he wanted to ask the lecturer, though he did not expect him to answer it at the moment. He wanted to know how all this was going to affect the most important body of men in the Empire, namely, the merchant seamen of England. These men came and went from one ship to another. They were away from England when the opportunity for voting came along, they had practically no voice in affairs because of the extraordinary manner of their employment. They could only spend very short intervals with their wives and families.

The speaker was inclined to agree with the lecturer in his retrospect. When he himself looked back on his fifty-eight years at sea and saw the wonderful changes that had taken place during that period, not only in the ships themselves, but in the conditions under which the men lived, he felt a great sense of amazement. Much of it was due to the Government, which had been in some measure maligned, some was due to Plimsoll, that great man, and some was due to his friend and enemy, Havelock Wilson. It was amazing what had happened. To take one relatively small matter, on which he had recently been reading a paper before the Society, the improvement in lighthouses during the last quarter of a century. And, of course, there as elsewhere, the change was not yet finished. Possibly many lighthouses would disappear in the future with the coming of wireless directional. But a survey of the past filled him with hope.

MR. G. H. STUART-BUNNING, after a reference to the fact that they had a Scottish chairman and a Scottish lecturer, fell foul of the Scottish tale of James Watt and the kettle, which was a Scottish myth. The steam engine was really discovered by two Englishmen, and all that James Watt did was to make profit out of somebody else's idea! The lecturer had been telling them about industry in fifty years' time, but what he had really been depicting was industry as it ought to be now. He had spoken of driving nails into the coffin of industrial unrest. It was as well to be sure when you drove nails into a coffin that there was a body in it as well! He seemed to think industrial unrest had been brought about by a concatenation of circumstances for which nobody was to blame. That was not so. It had been

brought about to a great extent by a feeling that the workmen were not properly treated. He remembered some twenty years ago arguing before a committee of which the Chairman was a member that certain people ought to be brought within the Workmen's Compensation Act, and he did not find any readiness on the part of the employers even to discuss the question; on the contrary, they put up the most obstinate opposition. It was this feeling, of which so many workmen were aware, which created industrial unrest.

The lecturer had said that Parliament could not do these things. Good Heavens, Parliament spent half its time remedying the mistakes of the lawyers! On this very question which was being talked about, there was a period during which judges year after year gave certain decisions, and in the end the matter came to the House of Lords. And the lawyers had to be put right by a special Act which was passed in 1896. We should not require Houses of Parliament if we had sense—nor lawyers, either!

On one point he must differ from the Chairman entirely. He (the speaker) believed in the machine. He remembered some thirty-five years ago when he was a postman at the South Western office he had to truck up books and parcels on a very long slope—hard and heart-breaking work—and he was very glad when visiting there the other day to see that these parcels were taken up by mechanical conveyor. Machinery was a good thing. What was wanted was not the misuse of machinery, but its proper use.

With a good deal that the lecturer had said he agreed, but he could not agree that the trade unions were going out of existence. He did agree that they must alter and adapt their methods of working, but when the good times prophesied came—and he believed they were coming—it would be found that trade unions had their proper use and application. It was quite wrong to think that the trade union existed for combatant purposes. It fought only when it must, and an immense amount of work which trade unionism did consisted of negotiation, which must go on whatever changes might be made.

MR. CRAWFORD, in a brief reply, said that he was very much obliged for the discussion, and was glad to feel that a few differences of opinion had been introduced. It had been a special pleasure to him to hear the views of Mr. Appleton and other experts and to gather what was in their minds. He had not thought or said that trade unions should go out of existence, and with regard to his remarks about the inadvisability of political interference all he had meant was that it was for industry to "buck up" and look after its own affairs, and so render it unnecessary for politicians to interfere.

In closing the meeting,

THE CHAIRMAN (Mr. Barnes) said that he thought all would agree that they had had a very useful and interesting evening, and they were all very much indebted to Mr. Crawford. He believed they were all agreed that there was a better spirit prevailing in industry now than at any previous period in our history. The employers were more disposed than ever before to do the fair thing, and he believed there was a larger volume of feeling all round in favour of the fair thing. But he felt strongly that the workmen had only got their improved conditions as a result of organising themselves, and if they were going to retain those improved conditions they had got to keep their trade unions strong and ready to take any action that might be necessary. Trade unions for a long time to come were the only agencies that could be depended on to keep up the standard of labour. If they were weakened to-day,

it would happen inevitably, not as the result of malignant intention on the part of anyone, but by the ordinary operation of competitive laws, that the standard of labour would come down.

He was also of opinion that Mr. Crawford was unnecessarily hard upon the despised politician. The real beginning of the new era in industry might be dated not earlier than 1896, when Joseph Chamberlain succeeded in getting Parliament to pass the Workmen's Compensation Act, and this was followed by other measures of similar tendency. Mr. Crawford had rather under-estimated the importance of bringing the whole strength of the community into alliance with industry to see fair play. What the speaker wanted to see was not industry run as at present in separate regiments, each going its own way, but industry, on the part of employers and workmen alike, run as one army, each regiment co-operating as part of the army. If that standard were to be reached the aid of the State would have to be invoked to see fair play, and before that could come about something in the nature of a National Industrial Council representing the whole of the community must be established.

A vote of thanks was accorded to Mr. Crawford on the motion of Mr. Barnes, and a further vote of thanks to the Chairman on the motion of Sir Arthur Holbrook.

NOTES ON BOOKS.

THE PHASE RULE AND ITS APPLICATIONS. Sixth Edition. By Alexander Findlay, M.A., D.Sc., F.I.C., Professor of Chemistry, University of Aberdeen. London: Longmans, Green and Co., Ltd. 10s. 6d. net.

The appearance, nearly twenty-five years ago, of Messrs. Longmans' series of text-books of Physical Chemistry marked the opening of a new era in physico-chemical teaching in this country; and while most of the subsequent volumes were of considerable excellence, none eclipsed the treatise which was chosen to initiate the new collection.

The rarity of text-books devoted to the Phase Rule is (like the Phase Rule itself) not altogether easy of comprehension. The "examination value" of the subject is by no means small, and one would have thought it would make an irresistible appeal to the authors possessing the necessary gift of luminous exposition. In every general text-book of Physical Chemistry the Phase Rule is, of course, discussed *taille bien que mal* on elementary lines; but the reviewer can recollect only two other special text-books which have been published in English during the last twenty-five years, and those both differ widely in scope from Professor Findlay's. The result is that this book must have contributed appreciably to the intellectual development of the majority of living British chemists, which is a sufficiently remarkable achievement.

Minor alterations and improvements have been made from time to time, but the present edition has been more drastically revised, and to some extent re-written, under pressure of the continual accumulation of new observations and new views based upon them. So well has this been done that the work as a whole shows no sign of being in the slightest degree out of date.

What is perhaps a little open to question is whether more might not have been done to sympathise with and lighten the difficulties in arriving at a useful com-

prehension of this extremely involved subject. As in so many other text-books, one seems to find a tendency towards providing the student with knowledge which he can parade, when he would be very much better off with understanding which he could use.

A conspicuous example occurs in the treatment of the iron-carbon system. This is explicitly put forward, amongst others, as exemplifying the application of Phase Rule principles *already developed*; but the greater part of this system is concerned with equilibria, whose principles in point of fact are not discussed anywhere in the book, such as the relations between a compound of two components and their mutual solid solution; and between the solid solution and several allotropic modifications of one of the components. It seems a little doubtful whether a student gains much, except for examination purposes, by being able to reproduce the curves of a diagram which he does not fully understand; and it would surely have been profitable to indicate the rationale of these types of equilibrium, even if that were to involve the omission of the descriptive section of the iron-carbon system.

A somewhat similar tendency is to be observed in the sections dealing with the general philosophy of the subject, where less than two pages are devoted to the derivation of the Phase Rule, and hardly more than three to the enumeration of components. On these points, if on any, one would have thought that the duty of a text-book would be to give clear and full enlightenment, which might fairly claim priority over any kind of descriptive matter.

It may be admitted, however, that these questions are extremely disputable: what will not be disputed is that this text-book reaches an exceptionally high standard of merit.

HISTORY OF RADIO TELEGRAPHY AND TELEPHONY. By G. G. Blake, M.I.E.E.
London: Chapman & Hall, Ltd., 25s. net.

The rise and development of modern wireless communication has been so rapid that many ingenious schemes and inventions were probably abandoned in their infancy and completely forgotten before they received an adequate practical trial. The present volume will serve to remind the modern student of the majority, if not all, of these inventions; for the book is of the nature of an historical catalogue of the various schemes and ideas which have marked the development of radio communication since the earliest observations on electrical phenomena. For the non-technical reader a foreword is provided explaining briefly the modern view of electricity and its relation to matter and the ether. The reader is then carried through the early history of the wire telegraph and telephone instruments to the dawn of practical radio-telegraphy. Later chapters deal with the difficulties experienced in generating high-frequency oscillations by spark and arc methods in steadily increasing powers. The flood of inventions which accompanied the introduction of the thermionic valve are described, and the various applications of wireless to telephony, direction-finding, the transmission of photographs and television receive adequate recognition. The book is completed by a bibliography of 1125 references, and many workers in the wireless field will be indebted to the author for the immense labour he must have gone to in the compilation of the work. The production of the book is excellent in every detail. Large clear type is used throughout; misprints are few; and all the diagrams and photographs are exceptionally well reproduced.

R. L. SMITH ROSE,

A BIRD BOOK FOR THE POCKET. By Edmund Sandars, Oxford University Press.
London: Humphrey Milford. 7s. 6d. net.

In the preface the author explains the purpose of the book as follows: "The book was made for myself and is published in the belief that others may want what I wanted, namely, first, a book really small enough to carry in the pocket, with a text in clear type, but condensed to the utmost; secondly, drawings on the page facing the text and accurate enough in colour, form and size to avoid the need of long descriptions; and thirdly, all the birds, for better comparison, shewn in more or less the same position." After an introduction dealing with the special characteristics of birds or of certain groups of birds in regard to such matters as bodily structure, migration, nests, flight, etc., the main portion of the book is arranged so that every right-hand page contains a coloured plate and every left-hand page a short description of the birds illustrated on the opposite page. There is also a section devoted to eggs and an index.

The book appears to be admirably adapted for carrying in the pocket on country rambles (its size is 6 in. x 4½ in.), and would make a suitable gift to boys or girls in whom it is desired to cultivate a living interest in the country-side.

PHYSICS IN MEDICAL RADIOLOGY. By S. Russ, L. H. Clark, and B. D. H. Watters.
(Chapman and Hall.) 234 pp., 72 figs. 12s. 6d. net.

The authors of this book, who are all actively associated with the Middlesex Hospital, have largely had in mind the requirements of candidates for the several Diplomas in Medical Radiology in this country. There are introductory chapters on electrostatics, current electricity, electrical conductivity of gases and electromagnetic waves, followed by chapters on X rays, radioactivity, photography, electric motors, high-tension generators, physics of electrotherapy, etc. Two useful appendices deal respectively with X-ray and radium protection and a hospital radium service.

The writers have obviously been confronted with the task of putting a quart into a pint pot, and in the light of these limitations have succeeded in presenting a simple and attractive treatment of the diversity of subjects dealt with—a vital achievement when one recalls the aversion with which the average medical man is apt to regard physics, and in particular mathematics.

References to original papers are not given in the text, but a list of reference books is added at the end of the book. The index is a subject index only and does not include names of authors. The figures are very good and clear, and the publishers' share in the volume is worthy of praise. We may perhaps note two small printer's errors—on p. 38, where Friedrich is wrongly spelt, and on p. 108, where the formulae for anhydrous radium chloride and carbonate are incorrect.

MEETINGS OF THE SOCIETY.

ORDINARY MEETINGS.

Wednesday evenings at 8 o'clock.

APRIL 25—DR. J. M. RITCHIE, M.A., F.C.T.B., "The Education and Training of the Blind." CAPTAIN SIR BEACHCROFT TOWSE, V.C., K.C.V.O., C.B.E., Chairman of the National Institute for the Blind, will preside.

MAY 2.—WILLIAM TAYLOR, of Messrs. Taylor, Taylor, and Hobson, "Standardisation in Apparatus for Science Teaching." THE HON. SIR CHARLES A. PARSONS, O.M., K.C.B., LL.D., D.Sc., F.R.S., will preside.

MAY 9.—CAPTAIN R. W. LANE, "The Sterilisation of Milk." PROFESSOR R. SIENHOUSE WILLIAMS, M.B., C.M., B.Sc., D.P.H., Research Professor in Dairy Bacteriology, University College, Reading, will preside.

MAY 16.—W. WORBY BEAUMONT, M.Inst.C.E., "Modern Motor Car Design: Some Criticisms and Suggestions." ALAN A. CAMPBELL SWINTON, Esq., F.R.S., will preside.

INDIAN SECTION.

Friday afternoons at 4.30 o'clock.

Date to be hereafter announced:—

SIR JAMES MACKENNA, C.I.E., "The Sugar Industry in India, Java, and Mauritius."

DOMINIONS AND COLONIES SECTION.

Tuesday afternoons at 4.30 o'clock.

MAY 22.—CAPTAIN SIR CECIL ARMITAGE, K.B.E., C.M.G., D.S.O., "The Gambia Colony and Protectorate" (illustrated by lantern slides). LIEUT.-COL. THE RIGHT HON. SIR MATTHEW NATHAN, P.C., G.C.M.G., LL.D., formerly Governor of the Gold Coast, will preside.

DR. MANN LECTURES.

A. G. HUNTLEY, May Construction Company, Ltd., "Applied Architectural Acoustics." Three lectures. April 16, 23 and 30.

The syllabus was published in the *Journal* dated January 27th.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

- MONDAY, APRIL 23. Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Mr. H. S. Goodhart Rendel, "The Work of Temple Moore."
- Civil Engineers, Institution of, Great George Street, S.W. 6.30 p.m. Mr. H. Heywood, "Pulverized Coal Systems."
- East India Association, at Caxton Hall, Westminster, S.W. 3.30 p.m. Mr. W. H. Arden-Wood, "The Problem of the Domiciled Community in India."
- Geographical Society, at the Eolian Hall, 135, New Bond Street, W. 8.30 p.m. Mr. Francis Rodd, "Journeys among the Southern Tuareg."
- TUESDAY, APRIL 24. Anthropological Institute, 52, Upper Bedford Place, W.C. 8.30 p.m. Mr. Miles C. Burkitt, "South Africa's Past in Stone and Paint."
- Illuminating Engineering Society, at the Home Office Industrial Museum, Horseferry Road, S.W. 6 p.m. Discussion on "Daylight, Artificial Light, and Artificial Daylight: their Merits and Drawbacks," opened by Mr. J. S. Dow.
- Photographic Society, 35, Russell Square, W.C. 7 p.m. Meeting of Kinematograph Group.
- University of London, at the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Prof. Dr. Wilhelm Kalveram, "The Post-War Development of German Banking." (Lecture I.)
- WEDNESDAY, APRIL 25. Civil Engineers, Institution of, Great George Street, S.W. 6.30 p.m. Annual General Meeting of the Association of London Students.

- THURSDAY, APRIL 26. Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m. Herr C. Dornier, "Flying Boats."
- University of London, at Birkbeck College, Bream's Building, Fetter Lane, E.C. 5.30 p.m. Prof. D. Debye, "The Electrical Theory of Molecular Constitution." (Lecture I.)
- At King's College, Strand, W.C. 5.30 p.m. Dr. K. Belar, "The Mechanism of Mitosis."
- At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Prof. Dr. Wilhelm Kalveram, "The Post-War Development of German Banking." (Lecture II.)
- FRIDAY, APRIL 27. Civil Engineers, Institution of, Great George Street, S.W. 7 p.m. Mr. J. C. Armstrong, "Pulverized Coal in Locomotive Furnaces."
- Cyclists' Touring Club, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m.
- Philological Society, at University College, Gower Street, W.C. 8 p.m. Dr. O. Vocadlo, "Purism II."
- Physical Society, at the Imperial College of Science and Technology, South Kensington, S.W. 5 p.m. (1) Prof. Will C. Baker, "Experiments with Mercury Jets and the Phenomena exhibited at their Impact with Steel and Glass." (2) Messrs. E. P. Perman and W. D. Urry, "The Elastic Constants of Glass." (3) G. E. Bell, "A Valve-maintained High-frequency Induction Furnace and some Notes on the Performance of Induction Furnaces."
- Royal Institution, 21, Albemarle Street, W. 9 p.m. Prof. Dr. A. M. Tyndall, "Carriers of Electricity in the Atmosphere."
- University of London, at Birkbeck College, Bream's Buildings, Fetter Lane, E.C. 5.30 p.m. Prof. D. Debye, "The Electrical Theory of Molecular Constitution." (Lecture II.)

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FRIDAY, APRIL 27th, 1928.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.(2.)

NOTICES.

NEXT WEEK.

MONDAY, APRIL 30th, at 8 p.m. (Dr. Mann Lecture.) A. G. HUNTLEY, of the May Construction Co., Ltd., "Applied Architectural Acoustics." (Lecture III.)

WEDNESDAY, MAY 2nd, at 8 p.m. (Ordinary Meeting.) WILLIAM TAYLOR, of Messrs. Taylor, Taylor and Hobson, "The Standardisation of Apparatus for Science Teaching." THE HON. SIR CHARLES PARSONS, O.M., K.C.B., LL.D., D.Sc., F.R.S., will preside.

COUNCIL.

A meeting of the Council was held on Monday, April 16th. Present:—Sir Philip Magnus, Bt., in the Chair; Sir Charles H. Armstrong; Mr. Llewelyn B. Atkinson, M.I.E.E.; Rt. Hon. George N. Barnes, C.H.; Mr. Peter MacIntyre Evans, M.A., LL.D.; Sir Alexander Gibb, G.B.E., C.B.; Rear-Admiral James de Courcy Hamilton, M.V.O.; Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S.; Sir Herbert Jackson, K.B.E., F.R.S.; Col. The Master of Sempill; Sir George Sutton, Bt.; Mr. J. Swinburne, F.R.S.; Mr. Alan A. Campbell Swinton, F.R.S.; Mr. Carmichael Thomas; Professor John Millar Thomson, F.R.S., and Sir Alfred Yarrow, Bt., F.R.S., with Mr. G. K. Menzies (Secretary).

It was reported that the Chairman, the Secretary and the Examinations Officer had given evidence before the Departmental Committee on Examinations for Part-time Students in support of the replies to the questionnaire approved by the Council in November last.

The question of the award of the Society's Albert Medal for 1928 was further considered.

Consideration of the balloting list for the new Council was begun and vacancies were declared.

It was reported that about £470 had now been received in response to the appeal for the preservation of Arlington Row, Bibury, Gloucestershire. The amount required to purchase the cottages, put them into thoroughly sound condition and provide a permanent fund for future repairs is £2,000.

The following candidates were duly elected Fellows of the Society:—

Babycon, M. Ardeshir, Ahmedabad, India.
 Bhathena, Shavaksha Fakirji, Bombay, India.
 Blackband, William Thomas, Solihull, Warwickshire.
 Bolton, Reginald Pelham, New York City, U.S.A.
 Brown, William Doughty, M.A., Chislehurst, Kent.
 Clack, Henry James, London.
 Cowles, Frederick Ignatius, Swinton, Lancs.
 Dundee Public Libraries, Dundee.
 Dunsheath, Percy, Sidcup, Kent.
 Fleming, A. P. M., Manchester.
 Franklin, Mrs. F. S., London.
 Fullwood, John, R.B.A., Hampton Hill, Middlesex.
 Gallagher, Louis B.A., London.
 Green, James, London.
 Hill, George Harold, Buxton, Derbyshire.
 Hobart-Bird, William, Cheltenham.
 Jackson, N. E., London.
 Kelley, John Douglas, London.
 Latham, Christopher, A.M.I.Mech.E., London.
 Munsell, Alexander Ector Orr, Baltimore, Md., U.S.A.
 Nelson, Thomas, Raleigh, North Carolina, U.S.A.
 Neville, William Henry, London.
 Parkington, Thomas R., Ipswich.
 Smith, Horace Fleming, London.
 Spence, T. F., J.P., Ripon, Yorks.
 Temple-Richards, Harold, London.
 Thomson, Miss E. Gertrude, R.M.S., London.
 Tily, Eugene James, Sutton, Surrey.
 Todd, Alderman Frederick, J.P., Manchester.
 Vyas, M. M., Ahmedabad, India.
 Witts, F. J., London.

A quantity of financial and formal business was transacted.

DR. MANN LECTURE.

MONDAY, APRIL 23rd, 1928. MR. A. G. HUNTLEY, of the May Construction Co., Ltd., delivered the second of his course of three lectures on "Applied Architectural Acoustics." The lectures will be published in the *Journal* during the summer recess.

PROCEEDINGS OF THE SOCIETY.

FIFTEENTH ORDINARY MEETING.

TRUEMAN WOOD LECTURE.

WEDNESDAY, 7TH MARCH, 1928.

SIR FRANK WATSON DYSON, K.B.E., LL.D., D.Sc., F.R.S., Astronomer Royal, in the Chair.

THE WIDER ASPECTS OF COSMOGONY.

By J. H. JEANS, M.A., D.Sc., LL.D., F.R.S.,
Secretary of the Royal Society.

Interest in scientific cosmogony is a recent, and still a very tender growth. Anthropologists and geologists tell us that man has existed on earth for something like 300,000 years; we must go this far back to meet our ape-like ancestry. Between them and us some 10,000 generations of men have walked the Earth, most of whom have probably given some thought, in varying degrees, to the significance of their existence and the plan of the universe.

But of these 10,000 generations of men, the first 9990 unhesitatingly regarded the earth as the centre, and terrestrial life as the central fact, of the universe. As was suited to its majesty and dignity as the abode of man, the earth stood still while the celestial sphere spun round it, covering in the earth much as a telescope-dome covers in the telescope. And this dome was spangled with stars, which had been thoughtfully added so as not to leave the central earth unilluminated at night. Ten generations at most have been able to consider the problem of their existence in anything like its proper astronomical perspective.

The total age of the earth far exceeds the 300,000 years or so of man's existence. The evidence of geology and of radio-activity in rocks in particular, shows that it must be something like 2,000 million years, which is several thousand times the age of the human race. Old Mother Earth must regard man as a very recent apparition indeed; he has just appeared to burrow into her, burn her forests, put her waterfalls into pipes, and generally mar the beauty of her features. If he has done so much in the first few moments of his existence, she may well wonder what is in store for her in the long future ages in which he is destined to labour on her surface. For in all probability the life in front of the human race must enormously exceed the short life behind it. A million million years hence, so far as we can foresee, the sun will probably be much as now, and the earth will be revolving round it much as now. The year will be a little longer, and the climate quite a lot colder, while the rich accumulated stores of coal, oil and forest will have long been burnt

up ; but there is no reason why our descendants should not still people the earth. Perhaps it may be unable to support so large a population as now, and perhaps fewer will desire to live on it. On the other hand, mankind, being three million times as old as now, may—if the conjecture does not distress our pessimists too much—be three million times as wise.

Looked at on the astronomical time-scale, humanity is at the very beginning of its existence—a new-born babe, with all the unexplored potentialities of babyhood. And until just now, its interest has been centred, absolutely and exclusively, on its cradle and feeding bottle. It has this moment become conscious of the vast world existing outside itself and its cradle ; it is learning to focus its eyes on distant objects, and its awakening brain is beginning to wonder, in a vague, dreamy way, what they are and what purpose they serve. Its interest in this external world is not much developed yet so that the main part of its faculties are still engrossed with the cradle and feeding bottle, but a little corner of its brain is beginning to wonder.

Taking a very gloomy view of the future of the human race, let us suppose that it can only expect to survive for two thousand million years longer, a period about equal to the past age of the earth. Then, regarded as a being destined to live for threescore years and ten, humanity, although it has been born in a house seventy years old, is itself only three days old. But only in the last few minutes has it become conscious that the whole world does not centre round its cradle and its trappings, and only in the last few ticks of the clock has any adequate conception of the size of the external world dawned upon it.

For our clock does not tick seconds, but years. A minute and a half ago the distance of a star was first measured and provided a measuring-rod for the universe. Ten seconds ago Shapley showed how the peculiar stars known as Cepheid variables provided a longer measuring-rod, and taught us to think in distances so great that light takes hundreds of thousands of years to traverse them. And, with the very last tick of the clock, Hubble, using the same measuring-rod, has found that the most remote objects visible in the biggest telescope on earth are so distant that light, travelling 186,000 miles a second, takes about 140 million years to come from them to us.

Not only is our vision of the universe continually expanding, but it is expanding at an ever increasing rate. Is this expansion destined to go on for ever ? So far as we can at present see, no ; for a general guiding principle, that of generalised relativity, fixes a limit, which we are fast approaching. According to this theory, space cannot extend for ever ; it has no limit, but is nevertheless finite like the surface of the earth. Without exploring and surveying the whole of the earth's surface, we can make a fair estimate of its total area by measuring its radius, which we can do by measuring its curvature at any one point. In the same way the total volume of space is fixed by a quantity, the curvature of space, which can be determined by measuring the density of distribution of matter in space. Space which contained no matter would go on

for ever, but the parts of space we can survey with our telescopes contain enough matter to show that we already see an appreciable fraction of the whole of space. It is as though our baby, watching ships coming from over the horizon, concluded that the earth's surface was curved, and formed a general rough conception of its size by imagining the observed curvature continuing until the earth's surface rounded back on itself.

Exact figures are impossible, but Hubble has calculated that space is not likely to extend to more than about a thousand times as far as the furthest nebula visible in the biggest telescope. Nothing prevents our going on and on in space beyond this distance, but, if we do, we merely come back to ourselves. The possessor of a sufficiently sensitive wireless apparatus may emit signals and pick them up a seventh of a second later after they have travelled round the world. In the same way a not inconceivable increase in the size of our telescopes would take us round the whole of space, and we should see the stars surrounding our sun by light which had travelled round the universe, not of course as they now are, but as they were 100,000 million years ago.

Such considerations make it improbable that the expansion of the universe can continue at its present rate for much longer. Having grasped that the world is round, the infant speedily forms a fair idea of its size. Our particular infant, mankind, has made the great discovery of the existence of the outer world, has formed some conception of its size, and adjusted his ideas, not by a process of slow revelation, but by a brain-flash of the last few seconds. In his mature years and his staid old age he is no doubt destined to make many sensational discoveries, but he can never again live through the immortal moment at which he first grasped the immensity of the outer world. You and I only live through a few ticks of his clock, and fate might have ordained that they should be anywhere in the three days that the child has already lived, or in the seventy long, and possibly tedious, years yet to come. The wonderful thing is that she has selected for us what is perhaps in some ways the most sensational moment of all in the life of our race.

The child sets its newly-awakened mind to work to adjust and co-ordinate a new array of facts. If the world wasn't made to surround its cradle, what purpose can it serve? If the lights of the great ships in the harbour were not designed to light its nursery at night, what can they possibly be for? And, most interesting problem of all, if the world is such a big affair, can there be other cradles and other babies?

These remarks will have served their purpose if they suggest to you that what I am rashly trying to put before you should not be judged as a finished science or the solution of a problem; it is rather the first confused gropings of the infant mind trying to understand the world outside its cradle. And if the impression produced by its first inexperienced glance at the outer world had to be described in a single word, it would probably select the word "immensity."

The immensity of space is measured by the figures already mentioned. Light and wireless signals travel at the same rate because, of course, they are essentially the same thing. And this thing takes a seventh of a second to travel round the world, and probably something like 100,000 million years to travel round the universe. The ratio of these times (2×10^{19}) measures the dimensions of the universe in terms of the familiar dimensions of the world; incidentally it also measures the expansion of our spatial ideas since Copernicus. The disparity of size is too great to be easily visualised. Suppose the size of our earth represented by a single atom a hundred millionth of an inch in diameter, then the range of vision of the biggest telescope is about represented by the whole earth, and the size of the whole universe, according to the theory of relativity, is represented by a stack of a thousand million earths.

Hardly less bewildering than the immensity of space is the immense amount and variety of matter it contains. The sun, which is a million times as big as the earth and 300,000 times as massive, proves to be something less than a grain of sand on the seashore. It forms one of a family whose number must certainly be counted in thousands of millions; Seares has estimated it at thirty thousand millions. This is not the only family of stars in space. Each of the great nebulae, such as those shown in figs. 1 and 2, is either a family of stars, or consists of stars in the making, or of matter which is destined ultimately to form stars. We can estimate the masses of these great nebulae by gravitational means, and each is found to contain enough matter to make a thousand million suns. This of itself will give some conception of the vast size of these nebulae, but to tell the whole story, it must be added that their colossal masses are so tenuous that each millionth part of an ounce is, on the average, as big as the Matterhorn. Think of a body which is bigger than the Matterhorn by as much as a thousand million suns is heavier than a millionth part of an ounce, and you have the size of any one of these great nebulae. Either of the two photographs would have to be enlarged so as to cover the whole of Asia before a body of the size of the sun became visible in them at all, even under the most powerful of microscopes.

Hubble estimates that about two million such nebulae are visible in the great 100 inch telescope at Mount Wilson, and that the whole universe has about a thousand million times the volume of that part of space visible in this telescope. Let us now multiply 1,000 million by 2 million, and the product by 1,000 million. The answer (2×10^{24}) gives some indication of the number of stars in the universe; the same number of grains of sand spread over England would make a layer hundreds of yards in depth. Let us reflect that our earth is one millionth part of one such grain of sand, and our mundane affairs, our troubles and our achievements, begin to appear in their correct proportion to the universe as a whole.



FIG. 1.—Lenticular nebula (N.G.C. 4594) with ring of dark matter surrounding equator.

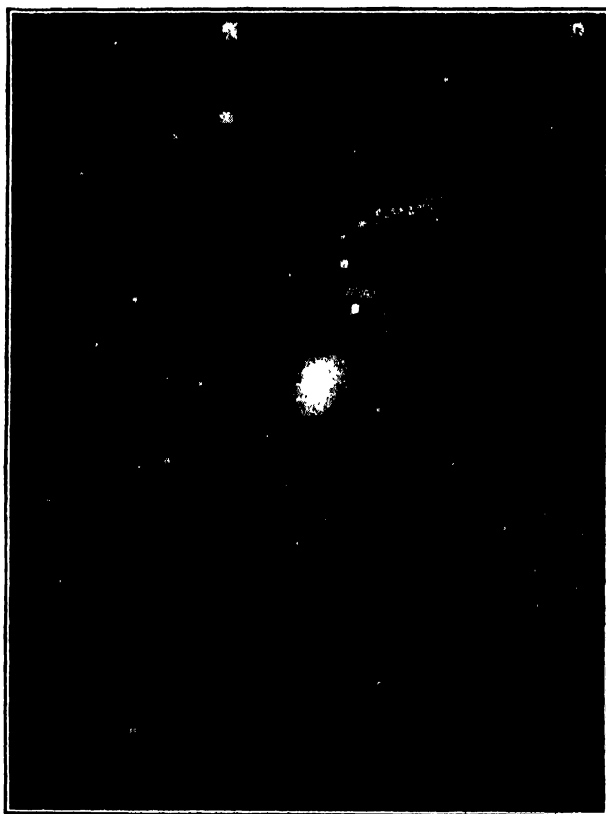


FIG. 2.—Spiral nebula in Ursa Major (M. 81).

While the stars may fairly be compared to grains of sand in number, they differ too much *inter se* for the comparison to be carried further. There is an enormous variety of big and little stars, of bright and faint stars, of red and blue stars, and of hot, hotter, and still hotter stars. The faintest of known stars (Wolf 359) emits only a fifty thousandth part of the light of the sun, while the brightest (S Doradus) emits 300,000 times as much light as the sun. The smallest known star (Van Maanen's star) is about the size of the earth; a million such stars could be packed inside the sun and leave room to spare. The largest known star (Betelgeux) is so large that 25 million suns could be packed inside it. Their ranges are greater than those between a search light and a glow-worm, or between balloons and bird-shot.

Yet the stars are essentially similar structures. A normal atom consists of a central nucleus round which a number of electrons revolve like planets round the sun—a miniature solar system, in fact, in which the vacant space far exceeds that occupied by matter. With great heat the electrons begin to break loose and fly off at a tangent. The central temperatures of the stars can be calculated with fair precision, and prove to be so high that most of the electrons must have already broken loose from their atoms. Of recent years a great deal of labour has been devoted to testing the hypothesis that practically all the electrons have so broken loose, the stripped atoms and electrons flying about in a general hurly-burly like the molecules of a gas. But the hypothesis has proved disappointing, and a much more probable hypothesis, is, I think, that the atoms are not stripped quite bare, but that in most stars they retain a few rings of electrons which give the atoms so much size that they jostle one another about like the molecules of a liquid. This hypothesis explains beautifully the otherwise puzzling fact that stars of large mass fall into distinct groups, of what may almost be described as "standardised" sizes. On the "liquid-star" hypothesis these different sizes correspond to the different sizes possible for the stellar atoms, which may have 0, 1, 2 or 3 rings of electrons left, but cannot have fractional numbers. The largest stars of all, such as Betelgeux, have three rings left, while minute stars, such as Van Maanen's star, consist of atoms most of which are stripped quite bare, so that there is almost no limit to the closeness with which they can be packed together. An average handful of the matter of which this star is composed would contain about ten tons.

Thus the observed sizes of the stars proclaim the secret of the structure of the atom. The sizes of the stars are discontinuous because the sizes of atoms broken down to different stages are discontinuous. These discontinuities can be traced in turn to the discontinuities which form the central feature of the new quantum-dynamics. Thus the distinguishing characteristic of the laws which govern the most minute processes in nature is transmitted directly into the large scale phenomena of astronomy and governs the distribution of the huge masses of the stars. The infinitely great is never very far from the

infinitely small in science, but it would be hard to find a more sensational illustration of the unity of science than that I have just given.

The standard sizes of stars predicted by this theory depend on the atomic weights of the atoms of which the star is composed. Thus the observed sizes of the stars disclose the atomic weights of the stellar atoms; they indicate that the stellar atoms are probably rather heavier than the heaviest atom, uranium, known on earth. The atoms which reveal their presence in stellar spectra are, of course, atoms of the ordinary terrestrial elements—hydrogen, iron, calcium, and the like. These, being the lightest atoms in the star, must naturally float up to its surface, and as the earth was originally formed out of the surface of the sun, the earth is necessarily composed of them. But it now appears likely that down in the depths of the stars are other unknown and heavier atoms. We may almost say that it must be so, for no terrestrial atoms, not even radium or uranium, can produce anything like the amount of energy which these stellar atoms are observed to produce.

The immensity of space is paralleled by that of time. We can estimate the ages of stars from the impression that time has made upon them, just as we estimate the age of a tree from the number of subdivisions of its stem, or of rings in its cross section. There are three principal methods of doing this. The orbits of binary stars, which are circular at birth, are gradually knocked out of shape by the forces from passing stars. As we can calculate the rate at which this process occurs, the shape of stars' orbits can be made to reveal their ages. The moving clusters provide a second method. Groups of bright stars such as the Great Bear, the Pleiades, Orion's belt are often found to consist of exceptionally massive stars which move in regular orderly formation through a jumble of slighter stars, like a flight of swans through a confused crowd of rooks and starlings. Swans, however, are conscious beings, and continually adjust their flight so as to preserve their formation. The swan-like stars cannot do this, so that their orderly formation must in time be broken by the gravitational pull of other stars. When this happens the lighter stars are naturally knocked out of formation first, while the most massive stars retain their formation longest. This agrees with what is observed, and as we can calculate the time necessary to knock out the lighter stars, we can at once deduce the ages of those which are left in. A third method of investigation rests upon a rather abstruse dynamical theorem, which shews that after a sufficient time the energies of motion of the different types of stars must tend to equality, the little stars making up for the smallness of their mass by the rapidity of their motion. Seares has shewn that the stars near the sun have nearly attained to this ideal state, and as we can calculate the time needed to establish it, we can again deduce the ages of the stars.

It is gratifying and significant that all three lines of investigation lead to the same result: the stars are found to be some millions of millions of years old, perhaps from 5 to 10 millions of millions. We cannot state their age with

much precision, but it is the general order of magnitude, not the exact figure, that is important.

Year after year, century after century, for millions of millions of years the sun radiates enough energy from each square inch of its surface to keep a 50 h.p. engine continually in action ; still hotter stars may radiate as much as 30,000 h.p. per square inch. If this energy were produced by the combustion of coal, the stars would all be completely burnt out in a few hundreds or thousands of years. Where, then, shall we find a source of energy to last millions of millions of years ?

Over twenty years ago I drew attention to the enormous store of energy made available by the annihilation of matter, by positive and negative electrons falling into and annihilating one another, thus setting free the whole of their intrinsic energy as radiation. On this scheme neither energy nor matter had a permanent existence, but only a sort of sum of the two ; each was, theoretically at least, convertible into the other. Whether energy is ever transformed into matter we do not know ; probably not. But the falling together of electrons and protons forms the obvious mechanism for the transformation of matter into energy, and it now seems practically certain that this is the actual source of the radiation of the stars. A beam of radiation exerts pressure on any surface it falls upon, just as a jet of water does or a blast of air. The reason is that radiation carries mass about with it, and electromagnetic theory tells us the amount of this mass. For instance, we can calculate that a search-light which is radiating 50 horse-power of energy is discharging mass into space with the radiation at the rate of a gramme and a quarter a century ; with sufficiently delicate adjustments it might even be possible to observe the recoil of the search-light. Indeed, the pressure of radiation has actually been measured, although not in this particular way. New mass is of course being continually fed into the search-light by the electric current. Each square inch of the sun's surface is in effect a searchlight discharging radiation into space at the rate of 50 horse-power, and so is discharging mass at the rate of a gramme and a quarter a century, and the sun's surface is so large that the sun as a whole is discharging mass into space at the rate of 250 million tons a minute. Now the sun has no source of replenishment. It must have weighed 360,000 million tons more yesterday than to-day, and by to-morrow will weigh 360,000 million tons less. These are not mere speculative statements ; they rest on observation, and on generally accepted principles which are directly confirmed by observation.

Allowing for the fact that a more massive star emits more radiation than a less massive one, we can calculate that five or ten million million years ago the sun must have been several times as massive as it is to-day, so that it has already lost most of the mass it had at birth. Of each ton it had at birth only a few hundredweights at most remain to-day. The loss of mass which accompanies radiation is, then, no mere academic hair-splitting. It is a real

astronomical phenomenon, and young stars must be many times as massive as old stars.

There is a certain amount of direct evidence of this change of mass. The radiation of the stars imposes an endlessly recurring capital levy upon their masses which, as observation shews, is graduated and increases very steeply indeed for the richest stars. The levy makes all the stars poorer, but it also tends to equalise what wealth remains ; the older the stars get, the more nearly equal their impoverished masses become. This is a large part of the reason why the stars are nearly equal in mass. The process is most clearly marked in the binary systems, which have been formed by a single star breaking into two. The two component stars of such a system are necessarily of the same age, and it is a matter of observation that the small stars of old systems are nearer to equality of mass than the massive stars of young systems.

Thus observation and theory agree in indicating that the universe is melting away into radiation. Our position is that of polar bears on an iceberg that has broken loose from the icepack surrounding the pole and is inexorably melting away as the iceberg drifts to warmer latitudes and ultimate extinction.

Five million million years ago the sun had stored up within it the energy which was destined to provide its light and heat until to-day, and the mass of this energy was many times the present mass of the sun. No means is known by which so much mass could be stored except in the form of electrons and protons. Thus we must suppose that the radiation of the sun through these millions of millions of years has been produced by the annihilation of electrons and protons which existed in it originally, but no longer exist now. These electrons and protons are pure bottled energy ; the continuous breakage of these bottles in the sun sets free the radiation which warms and lights our earth, and enough unbroken bottles remain to provide light and heat for millions of millions of years to come.

The amount of energy made available in this way is amazing. The annihilation of a pound of coal a week would produce as much energy as the combustion of the five million tons a week which are mined in the British Isles, while a single drop of oil would take the Mauretania across the Atlantic. When we speak of the efficiency of a steam engine as 5 per cent. or so we regard complete use of the thermal energy of combustion as 100 per cent. efficiency. If we measure the work done against the total intrinsic energy of the fuel, as made available by its complete annihilation, the efficiency is more like 0.0000001 per cent. On this scale the efficiency of the sun and stars is exactly 100.00 per cent.

Modern physical theory shews that the annihilation of an electron must produce a single flash of radiation of wave-length far shorter than any we can produce on earth. As this radiation threads its way through a star, its wave-length is continually increased, or, to use the technical term, the radiation is continually softened. In time it becomes γ -radiation, then hard X-radiation,

then soft X-radiation, and finally it emerges from the surface of the star as ordinary light and heat. Consider, however, an electron which is annihilated not inside a star but outside in free space, or in one of the almost transparent nebulae. The short wave-length radiation now undergoes no softening, but travels on until it meets something capable of checking it. Thus all astronomical bodies, including the surface of the earth, ought to be under continual bombardment by radiation of shorter wave-length, and consequently of greater penetrating powers, than any we can produce on earth.

Many years ago such radiation was detected in the earth's atmosphere by McLennan, Rutherford and other observers; it has recently been studied in detail by Millikan and others. There is no reason to doubt that it originates just where it ought to, namely, in the great nebulae, and its amount is about what it ought to be if it is evidence of the whole universe melting away into radiation. Again, we are not dealing with a minute phenomenon of mere academic interest. In a sense this radiation is the most fundamental physical phenomenon of the whole universe, most regions of space containing more of it than of visible light or heat. Your bodies and mine are traversed by it night and day. Short of going down into a mine or in a submarine we cannot escape it, and it is so intense that it breaks up several million atoms in each of our bodies every second. It may be essential to life or it may be killing us.

The stars are almost certainly born in vast nebulae of the type shewn in Figs. 1 and 2. These nebulae shew a great variety of shapes, but a single thread connects them all; they are the shapes of huge masses of gas endowed with different amounts of rotation. So definitely is this the case that when Hubble recently tried to classify the shapes of these nebulae, deliberately and avowedly shutting his eyes to all theoretical considerations, he found that purely observational considerations compelled him to classify them in precisely the sequence I had predicted on theoretical grounds some ten years earlier.

A huge mass of gas which was entirely devoid of rotation would of course assume a strictly spherical shape; rotation would flatten this shape out, just as the earth is flattened by its rotation, until ultimately most of the matter was spread out in a thin disc. We see the process beginning in Fig. 1, and it is nearly complete in Fig. 2. But mathematical theory shews that the thin disc-like structure could not remain a mere featureless mass of gas. Just as the cooling of a cloud of steam causes it to condense into drops of water, so the cooling of a cloud of gas causes it to condense into detached masses. We see the phenomenon in progress in nebular photographs; it is a necessary theoretical consequence of the laws of gases and the law of gravitation. Now the same theory which predicts that the phenomenon must happen, predicts the scale on which it will happen. We can calculate how much matter will go to the formation of each "drop," and the calculated masses of the drops come

out to be just about the same as the masses of the stars. And indeed these drops are stars, and the process just described is that of the birth of stars. Unmistakeable stars have been observed in the outer regions of many of the spiral nebulae. It is naturally not possible to identify every observed spot of light with a star, but some of them shew precisely the same peculiar fluctuations of light as characterise a certain class of variable star, and these put the identity of these particular spots of light beyond all reasonable doubt.

In these nebulae, then, we are watching the birth of stars, the transformation of an inchoate mass of gas into an "island universe" of stars. Indeed Hubble found it necessary to end up his classification of nebulae with clouds of stars. At one end of his continuous sequence is a nebula, shaped like a mass of rotating gas, in which not a single star is visible: at the other end a star-cloud in which nothing but stars are visible. Our galactic system of stars is probably the final product of just such a transformation, the milky way still recording the position of the equatorial plane of the original nebula.

Stars born in this way may meet with a variety of accidents and these result in different observed astronomical formations. A star may rotate too fast for safety, just as a flywheel may; when this happens it breaks into two and the two stars so formed revolve endlessly about one another as a binary system. Two stars may run into one another, although this is very rare. A more common occurrence is for two stars to escape running into one another by a narrow shave. When this happens huge tides are raised on the two stars involved, and these may take the form of long streamers of gas, which ultimately condense into "drops" just as did the gas in the outlying regions of the spiral nebulae. It seems reasonably certain that the planets were formed in this way.

The birth of the solar system, then, resulted from the close approach of two stars, and if a second star had not happened to come close to our sun, there would have been no solar system. It may be thought that with a life of millions of millions of years behind it, one star or another would have been certain to come near enough at some time to tear planets out of the body of our sun. Calculation shews the reverse; even after their long lives of millions of millions of years, only about one star in 100,000 can be surrounded by planets born in this way. A quite unusual accident is necessary to produce planets, and our sun with its family of attendant planets is rather of the nature of an astronomical freak.

In the thousand million stars surrounding our sun there are, at a moderate computation, not more than ten thousand planetary systems, because there has not been time for more than this number to be born. They are of course still coming into existence; calculation suggests a birth rate of about one per thousand million years. Thus we should have to visit thousands of millions of stars before finding a planetary system of as recent creation as our own, and we should have to visit millions of millions of stars before finding a planet on

which civilisation, and interest in the outer universe, were as recent a growth as are our own. We are standing at the first flush of the dawn of civilisation, and are terribly inexperienced beings.

It may be suggested that the creation of planetary systems is also only beginning, and that in time every star will be surrounded, like our sun, by a family of planets. But no; the stars will have dissolved into radiation or disappeared into darkness before there is time for this to happen. So far as we can judge, our part of the universe has lived the more eventful part of its life already; what we are witnessing is less the rising of the curtain before the play than the burning out of candle-ends on an empty stage on which the drama is already over. There is not time for many more planets to be born.

Now planets are the only places we know where life can exist. The stars are too hot; even their atoms are broken up by the intense heat. Nebulae are in every way unsuitable; even if cool solid bodies exist in them they would probably be so drenched with highly penetrating radiation as to render life impossible. Life demands a special type of matter, such as does not produce intense light and heat by transforming itself into radiation. We find it only in the surfaces of the stars, which are too hot for life, and in the planets which have been pulled out of these surfaces.

On any scheme of cosmogony, life must be limited to an exceedingly small corner of the universe. To our baby's wonderings whether other cradles and other babies exist, the answer appears to be that there can at best be very few cradles, and there is no conceivable means of knowing whether they are tenanted by babies or not. We look out and see a universe consisting primarily of matter which is transforming itself into radiation and producing so much heat, light and highly-penetrating radiation as to make life impossible. In rare instances, special accidents may produce bodies such as our earth, formed of a special cool ash which no longer produces radiation, and here life may be possible. But it does not at present look as though Nature had designed the universe primarily for life; the normal star and the normal nebula have nothing to do with life except making it impossible. Life is the end of a chain of by-products; it seems to be the accident, and torrential deluges of life-destroying radiation the essential.

There is a temptation to base wide-reaching inferences on the fact that the universe as a whole is apparently antagonistic to life. Other quite different inferences might be based on the fact of our earth being singularly well-adapted to life. We shall, I think, do well to avoid both. Each oak in a forest produces many thousands of acorns, of which only one succeeds in germinating and becoming an oak. The successful acorn, contemplating myriads of acorns lying crushed, rotten or dead on the ground, might argue that the forest must be inimical to the growth of oaks, or might reason that nothing but the intervention of a special providence could account for its own success in the face of so many failures. We must beware of both types of hasty inference.

And, in any case, our three days old infant cannot be very confident of any interpretation it puts on a universe which it only discovered a minute or two ago. We have said it has 70 years of life before it, but in truth its expectation of life would seem to be nearer to 70,000 years. It may be puzzled, distressed and often irritated at the apparent meaninglessness and incomprehensibility of the world to which it has suddenly wakened up. But it is still very young ; it might travel half the world over before finding another baby as young and inexperienced as itself. It has before it time enough and to spare in which it may understand everything. Sooner or later the pieces of the puzzle must begin to fit together, although it may reasonably be doubted whether the whole picture can ever be comprehensible to one small, and apparently quite insignificant, part of the picture. And ever the old question obtrudes itself as to whether the infant has any means of knowing that it is not dreaming all the time. The picture it sees may be merely a creation of its own mind, in which nothing really exists except itself ; the universe which we study with such care may be a dream, and we brain-cells in the mind of the dreamer.

DISCUSSION.

THE CHAIRMAN said he was sure that all those present had greatly enjoyed Dr. Jeans' lecture. Dr. Jeans reminded him of the lady who spoke a great word in a very easy tone of voice ; he talked of the large distances and times which had been expanding and expanding, at any rate in their lifetime. Astronomical times had expanded as much since Lord Kelvin's day as they had done between the times of Archbishop Ussher and Lord Kelvin. He thought the figure which they would remember best was that with regard to the sun losing 360,000 million tons a day. That seemed to him to be an extraordinarily impressive figure. At first sight it seemed to be almost incompatible with the long duration of the sun in the past and its long future duration. A good deal of what Dr. Jeans had said had come from his own researches. Dr. Jeans, besides being a mathematician, was also a member of the Mount Wilson Observatory, where he had helped, as he had helped people in England, to put observational facts into order, and to make deductions therefrom. One of Dr. Jeans' most striking deductions was that with regard to the small number of habitable worlds. Dr. Jeans' researches on rotating fluids led him to make it quite clear that the Solar System could not have come about in the way in which it was supposed to have done by Laplace. He had come to the conclusion that the only way in which a planetary system could have been formed was by the near collision of two bodies, and the lecture had therefore brought them back to the interesting view that there were very few habitable worlds in the Universe, that life was a very rare thing, and that it possibly occurred even only on the Earth. He had much pleasure in proposing a cordial vote of thanks to Dr. Jeans for his intensely interesting lecture.

MR. ALAN A. CAMPBELL SWINTON, F.R.S., said that he intended to say only one or two words, because the subject was quite overwhelming. Dr. Jeans had the most extraordinary power of making one think that one understood things.

No doubt those present thought that they understood a great deal at that moment, but he wondered how much they would understand on the following morning. He understood that he was going to be followed by Sir Oliver Lodge, who might have something to say which was worth saying; and he would therefore merely conclude by seconding a very cordial vote of thanks to Dr. Jeans for one of the most marvellous discourses which he had ever heard.

SIR OLIVER LODGE, M.A., LL.D., D.Sc., F.R.S., said that he doubted very much if any of those present had before heard a more comprehensive hour's discourse—from Genesis to Revelation. Earlier in the evening some of those present had attended a lecture by Professor Schrödinger at the Royal Institution on the latest theories in physics. That lecture had been quite different from the one to which they had just listened; it was gymnastics on the blackboard and high mathematics. As everyone knew, Dr. Jeans was quite competent to do any amount of gymnastics on the blackboard, but he had spared them the blackboard and come down to the level of his hearers, giving them a most concentrated view of existence beginning with facts which more or less everybody knew, and leading up to higher things and to some of his own researches, as the Astronomer Royal had said, in such a way that unless one had read some of Dr. Jeans' papers one could not follow anything like the full meaning of the present lecture. There was a desperate lot of meaning in them, and some of the theories were not without controversy. Dr. Jeans had told them that it was not the exposition of a finished science that he had been giving. They had been seeing science growing, and he (the speaker) thought that they should guard against the illusion of supposing that these things were done easily. The results were given to them in popular form, but they were not got in that form; very serious work underlay even some of the simplest things that had been said. They were living in an extraordinary time, and the progress that was being made in England and in America was astonishing. Astronomy was becoming almost an American science, because they had such splendid instruments there as well as fine men, and such heaps of money; America had been able to go ahead at a great rate in observation, but this country shared the benefit of the result. That was the advantage of science; everything was brought together and compared, and what was discovered in one part of the world was common property everywhere.

He would like to comment upon one or two things which Dr. Jeans had said. He always felt very diffident about saying anything of a questioning nature, because Dr. Jeans was very critical, but he (the speaker) was interested and a little surprised that Dr. Jeans seemed so certain about the finiteness of space. No doubt they had been familiar with the idea for some time, through Einstein and others, but Dr. Jeans seemed to think that it really was a definitely established fact that space was finite, so that if they went far enough in one direction they would not come to a boundary, but would come back to the starting place; if they went in one direction they would come back in another. Of course that was so on the surface of the Earth, and that was called curvature. Mr. Hinkler had flown to Australia, and he could have gone on—there was nothing to stop him apparently—for another sixteen days or so, and it would have brought him back again to Croydon, and then he would have said: "The Earth's surface is curved." The same thing was said by Dr. Jeans about space. He (the speaker) presumed that a beam of light sent out perfectly parallel so that it did not get dissipated would illuminate the sender's back; though it would be a fearful time on the journey, having so far to go.

If space was finite was time finite too? He did not know what the philosophers would make of these things when they got hold of them. It modified one's view of existence, but they did not want to be too certain that there was nothing to be said against it. Curvature depended upon the presence of matter. If matter ceased to be, beyond Hubble's furthest nebula, then space might straighten itself out again. He was also rather surprised at the mention of complex atoms in the stars. He confessed that he had thought that the matter in the stars at that high temperature would be of a simpler kind than they had on the Earth. They had 92 different atoms on the Earth, because they were only 300 degrees above absolute zero. Inside the stars the temperature was more like 40 million degrees, and he would have expected the chemical atoms there to be simpler. If he understood the lecturer aright, Dr. Jeans held that the heavy atoms, such as uranium, would hold together and be more likely to exist there than on the earth, and that the lighter atoms would get broken up. He presumed that that was why Dr. Jeans held the view that in the stars the molecules cohered together as in a drop of water, and were not loose disjointed things like the molecules in a gas. That was no doubt a difficult and somewhat controversial subject, and he did not express any opinion upon it.

Then there was the final remark that Dr. Jeans made about the cosmic rays, which were often called Millikan's rays, because Millikan investigated them with great pertinacity. He (the speaker) had no idea that they were going to be of such importance, and he did not know that Dr. Jeans had calculated their frequency and found it to be "about right." When one said with regard to things in nature that they were right, it really meant that we were beginning to get hold of the right end of the stick and beginning to understand them; evidently Dr. Jeans was beginning to understand the cosmic rays. He (the speaker) had not yet understood them fully. If what had been said during the evening were published in a newspaper, about their destroying the cells of people's bodies, they would have old ladies and other people writing letters on the subject. It was curious that these cosmic rays should now have been discovered, and since they were so penetrating they might be doing beneficent work. He had always felt that there was something in the outer atmosphere not quite explained by chemistry. He supposed that they got more of them in the fresh air than they did enclosed in a building, however penetrating the rays were. He wondered that any succeeded in penetrating the atmospheric screen, but they would get more if they climbed to the hill tops. It was an argument for mountain climbing, if one wanted these cosmic rays; they would get more up there.

Dealing with the loss of material from the stars in generating ordinary radiation, he felt constrained to ask a question. If this radiation was going on from all these thousands of millions of millions of stars, and through all these thousands of millions of millions of years, and if the Universe were finite, he really wanted to know where all the radiation was, and what had become of it. Was radiation ever going to turn into matter, or what was the end of it? Did the Universe only result in radiation, or was there going to be some other termination more justifiable after all the trouble that had been taken?

DR. HUBBLE (of the Mount Wilson Observatory, U.S.A.) wished to express his appreciation for the opportunity of hearing Dr. Jeans in one of his less mathematical moments. He had long admired Dr. Jeans' ability along the lines of non-mathematical exposition in writing, but this was the first time that he had ever heard him give an oral exposition. It was a far cry from examining photographic plates with

a microscope to what they had heard that night. The Universe might have been constructed on any one of an infinite number of patterns, and Dr. Jeans took the data of observation and told them which particular pattern was used in their own universe. The contributions of American astronomy were almost wholly observational, and his own rôle was that of an observer to help to supply the data of observation. For their significance, and for their interpretation, America was looking to England, to Dr. Jeans and to his associates.

THE CHAIRMAN said that he was sure that the vote of thanks would be received enthusiastically, and that they all felt that their hearty thanks were due to Dr. Jeans for the delightful lecture which he had given to them.

The vote of thanks having been carried unanimously, the meeting terminated.

NOTES ON BOOKS.

THE SOUTH AMERICAN HANDBOOK, 1928. London : South American Publications, Ltd., 2s. 6d. net.

The contents of the South American Handbook comprise general notes on physiographical features, travel, employment, climatic conditions, steamship routes, commercial products, and sport, in addition to separate sections on the various States of Latin America, including Central America and Mexico. The portions of the guide-book dealing with individual States contain information relating to the hotels, museums and public buildings of the capital, together with a short note on each of the principal towns, sections on climatic conditions, agricultural and mineral resources, foreign trade, industrial development, and regulations affecting tourists, immigrants and commercial travellers.

The guide-book is printed on thin paper and forms a handy and compact volume, which should be useful to anyone visiting South or Central America.

CHARLES LETTS'S ENGINEER'S DIARY. By J. E. Dodsworth. London : Charles Letts and Co. 3s., or in refillable case, 6s.

Messrs. Charles Letts's Engineer's Diary for 1928 contains, as in previous years, a very extensive collection of tables, formulae and other information of special use to the engineering and kindred professions, as well as a number of new features, *e.g.*, tables of weights of round and square bars, of the shrinkage of castings, and the safe shearing strength of iron rivets. Useful additions have also been made to the pages of General Information. The diary is printed on thin paper and is of a convenient size for carrying in the pocket, and may be obtained from Messrs. Charles Letts and Co., or from any stationers.

CHEMICAL ENCYCLOPEDIA. By C. T. Kingzett, F.I.C., F.C.S. Fourth Edition. London : Bailliere, Tindal and Cox. 35s. net.

The author of this well-known encyclopedia was one of the original founders of the Institute of Chemistry fifty years ago, and has always been actively interested in what used to be called the "diffusion" of chemical knowledge.

Though compiled mainly for the information of business men and members of non-chemical professions, the book contains enough information to be of real value to chemists; and the author explains, in the preface to the third edition, that it

has been thought desirable to replace the original title—"The Popular Chemical Dictionary"—by an alternative carrying a more critical implication. In the main this is amply justified, but it is only to be expected that the theoretical sections of such a work will fail to reach any very satisfactory standard: facts can often be sufficiently accurately summarized, but complex principles are not amenable to the same process.

The conception of strength and weakness in acids, for example, is not referred to at all under any easily discoverable heading. The general definition of an acid is "something that is sour," and although in a subsequent paragraph it is stated that all acids "may be regarded as hydrogen salts, in which the ionogenic hydrogen is replaceable by metals or basic groups," it would need a considerable degree of acumen to infer from this the true nature of an acid. Indeed, even in the discussion of electrolytic dissociation we are nowhere explicitly told that an acid is simply a substance which affords an appreciable supply of hydrogen ions in aqueous and other solutions.

One readily admits, again, that it would not have been practicable to discuss the critical relationships in fluids in such a manner as to convey any real understanding, but it is not easy to see what purpose is served by the following passage, which (save for bibliographical matter) constitutes the entire contents of this section: "The critical solution temperature is that at which the liquid and vapour phases of a heated solution are identical—i.e., in equilibrium—being the resultant of such an association of temperature and pressure that their specific volumes are identical. The temperature and pressure at which this state is realised are both defined as 'critical.' At a higher temperature the vapour becomes a gas. The critical temperature of water is $364^{\circ}\text{C}.$, and the critical pressure 195 atmospheres. The critical *sglution* point is the resultant of such temperature and pressure that two partially miscible solutions become consolute."

The critical phenomenon in pure fluids is a somewhat complex question, and in solutions is infinitely more so; yet solutions are here discussed first. The use of the term "critical solution temperature" in this connexion is an error: that term is reserved for a phenomenon which occurs in cases of partial liquid miscibility, (and which is in fact referred to in the last sentence of the quotation.) From the reference to water, one infers that at some undefined point we have ceased considering solutions and begun to consider pure fluids. The expression "identical," i.e., "in equilibrium," which might otherwise be highly misleading, is here quite incomprehensible, because obviously the liquid and vapour phases can be *in equilibrium* with one another over a whole range of temperature, and not merely at the temperature at which they attain an identity of properties. The assertion that "at a higher temperature the vapour becomes a gas" is as misleading as any assertion could well be.

The more practical information, and especially that which is concerned with industrial and pharmaceutical chemistry, is so much better than this that one regrets that the theoretical sections should appear at all—short bibliographies alone would have been infinitely preferable.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, APRIL 30. Actuaries, Institute of, Staple Inn Hall, Holborn, W.C. 5 p.m. Mr. P. C. Crump, "War-time Finance—A Résumé of Financial Conditions during and after the War as they affected Life Insurance Companies."

Farmers' Club, at the Whitehall Rooms, Hotel Metropole, S.W. 4 p.m. Mr. S. Colyer, "Conditions necessary for making the Sugar Beet Industry permanent in this Country."

University of London, at Birkbeck College, Bream's Buildings, Fetter Lane, E.C. 5.30 p.m. Prof. C. Debye, "The Electrical Theory of Molecular Constitution." (Lecture III.)

At King's College, Strand, W.C. 5.30 p.m. Prof. Hilda Johnstone, "The Monastic Chronicle." 5.30 p.m. Mr. H. Wickham Steed, "The Prelude to the War." (Lecture I.)
At University College, Gower Street, W.C. 5.30 p.m. Mr. Percival L. Witherby, "The Making of 'The Times'."

TUESDAY, MAY 1. University of London, at Bedford College, Regent's Park, N.W. 5.15 p.m. M. Edouard Champion, "Modern French Literature" (in French). (Lecture I.)
At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Prof. Dr. Franz Oppenheimer, "Tendencies in Recent German Sociology." (Lecture I.)
At University College, Gower Street, W.C. 5 p.m. Dr. J. H. Burn, "The Pharmacological Evidence for Current Methods of Treatment." (Lecture I.) 5.30 p.m. Dr. Dixon Ryan, "Civilisation in Transit."

WEDNESDAY, MAY 2. Analysts, Society of Public, at Burlington House, W. 8 p.m. (1) A. L. Williams, "Locust Kernel Gum and Oil." (2) Dr. W. R. Schoeller and Mr. E. F. Waterhouse, "Investigations into the Analytical Chemistry of Tantalum, Niobium and their Mineral Associates": XII. Observations on the Pyrosulphate Hydrolysis Method. (3) Dr. B. S. Evans and Mr. S. G. Clarke, "A New Precipitation Method for the Determination of Vanadium, and its Application to Steel Analysis." (4) Dr. P. Houseman, "Method for the Analysis of Liqueur Mass."

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C. 6 p.m.
Microscopical Society, 20, Hanover Square, W. Meeting of the Biological Section.

University of London, at Bedford College, Regent's Park, N.W. 5.15 p.m. M. Edouard Champion, "Modern French Literature" (in French). (Lecture II.)

At King's College, Strand, W.C. 5.30 p.m. Dr. W. B. Brierley, "Present Tendencies in the Study of Plant Disease."
At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Prof. Dr. Franz Oppenheimer, "Tendencies in Recent German Sociology." (Lecture II.)
5 p.m. Dr. Hubert Hall, "Some Common Factors in the Economic and Social Development of England in Mediaeval and Post-Mediaeval Times." (Lecture I.)
At University College, Gower Street, W.C. 5 p.m. Dr. J. H. Burn, "The Pharmacological Evidence for Current Methods of Treatment." (Lecture II.)

THURSDAY, MAY 3. Chemical Society, Burlington House, W. 8 p.m. (1) Messrs. P. D. Coppock, V. Subramaniam and T. K. Walker, "The Mechanism of the Degradation of Fatty Acids by Mould Fungi." (Part II.) (2) Messrs. A. Robertson and R. Robinson, "Experiments on the Synthesis of Anthocyanins." Part V. A Synthesis of 3- β -glucosidylpelargonidin chloride which is believed to be identical with callistephin chloride." (3) Mr. H. J. Emeléus, "The Phosphorescent Flame of Sulphur." (4) Messrs. A. J. Berry and T. M. Lowry, "Studies of Valency. Part IX.: Molecular Structure of Thallium Salts." (5) Thallium Tri-iodide (with Mrs. R. R. Goldstein). (6) Alkyl-derivatives (with F. L. Gilbert)."

Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C. 6 p.m.

Iron and Steel Institute, at the Institution of Civil Engineers, Great George Street, S.W. 10 a.m. Mr. B. Talbot, Presidential Address on "The History and latest Development of the Basic Open-Hearth Process." No. 2, Messrs. E. C. Evans and F. J. Bailey, "Blast-Furnace Data and their Correlation." No. 9, Messrs.

J. H. Jones, J. G. King and F. S. Sinnatt, "Reactivity of Coke." No. 15, Mr. T. Thomson, "The New Plant of the Appleby Iron Co., Ltd." No. 7, Messrs. J. E. Holgate and R. R. F. Walton, "Blast-Furnace Practice in Natal."

2.30 p.m. No. 14, Mr. H. J. Tapwell, "The Fatigue Resisting Properties of 0.17 per cent. Carbon Steel at Different Temperatures and at Different Mean Tensile Stresses." No. 8, Mr. J. A. Jones, "The Properties of Nickel Steels with Special Reference to the Influence of Manganese." No. 3, Messrs. A. B. Everest and D. Hanson, "The Influence of Nickel in Iron-Carbon-Silicon Alloys containing Phosphorus." No. 12, Mr. J. Swan, "The Effect of Silicon on Tungsten Magnet Steel." No. 16, Messrs. A. Westgren, G. Phragmén and Tr. Negresco, "On the Structure of the Iron-Chromium-Carbon System."

Linnean Society, Burlington House, W. 5 p.m.

Psychology, Institute of Industrial, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 5.30 p.m.

University of London, at Bedford College, Regent's Park, N.W. 5.15 p.m. M. Edouard Champion, "Modern French Literature" (in French). (Lecture III.)

At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Prof. Dr. Franz Oppenheimer, "Tendencies in Recent German Sociology." (Lecture III.)

At University College, Gower Street, W.C. 5 p.m. Dr. J. H. Burn, "The Pharmacological Evidence for Current Methods of Treatment." (Lecture III.)

FRIDAY, MAY 4. Chemical Industry, Society of, at Burlington House, W. 8 p.m. Mr. Francis H. Carr Presidential Address, "Some Chemical Engineering Aspects of the Fine Chemical Industry." Annual General Meeting.

Geologists' Association, at University College Gower Street, W.C. 7.30 p.m. (1) Mr. G. M. Lees, "The Chert Beds of Palestine." (2) Dr. P. K. Ghosh, "The Mineral-Assemblage of the Falmouth Granite."

Iron and Steel Institute, at the Institution of Civil Engineers, Great George Street, S.W. 10 a.m. No. 1, Report of the Committee on Heterogeneity of Steel Ingots. No. 5, Mr. V. Harbord, "A Comparison of the Most Important Methods Employed in the Cleaning of Blast-Furnace Gas." No. 6, Mr. W. H. Hatfield, "Heat-Resisting Steels. Part II.—Mechanical Properties."

2.30 p.m. No. 13, Messrs. T. Swinden and P. H. Johnson, "Chromium Steel Rails." No. 4, Mr. J. Newton Friend, "A Study of the Resistance of Overstressed Wrought Irons and Carbon Steels to Salt-Water Corrosion." No. 17, Mr. W. E. Woodward, "The Rapid Normalising of Overstrained Steel." No. 10, Messrs. A. L. Norbury and T. Samuel, "The Recovery and Sinking-in or Piling-up of the Material in the Brinell Test and the Effects of these Factors on the Correlation of the Brinell with certain other Hardness Tests." No. 11, Mr. H. O'Neill, "Twin-Like Crystals in Annealed α -Iron."

Philological Society, at University College, Gower Street, W.C. 8 p.m. Anniversary Meeting. Prof. D. Jones, Report on "Progress of Phonetics." Mr. N. P. Jeppson, "Report on Board of Comparative Philology."

Royal Institution, 21, Albemarle Street, W. 9 p.m. The Right Hon. R. McKenna, "Credit and Currency."

University of London, at King's College, Strand, W.C. 5.30 p.m. Dr. J. A. Bierens de Haans, "Animal Psychology for Biologists." (Lecture I.)

5.30 p.m. M. Denis Saurat, "Contemporary Provençal Poets." (Lecture I.)

5.30 p.m. Miss E. M. Ellis-Fermor, "The Machiavellian Villain in Marlowe and Shakespeare."

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.(2.)

NOTICES.

NEXT WEEK:

WEDNESDAY, MAY 9th, at 8 p.m. (Ordinary Meeting.) CAPTAIN R. W. LANE, "The Sterilisation of Milk." PROFESSOR R. STENHOUSE WILLIAMS, M.B., C.M., B.Sc., D.P.H., Research Professor in Dairy Bacteriology, University College, Reading, will preside.

NINETEENTH ORDINARY MEETING.

WEDNESDAY, APRIL 25th, 1928. CAPTAIN SIR BEACHCROFT TOWSE, V.C., K.C.V.O., C.B.E., Chairman of the National Institute for the Blind, in the Chair. A paper on "The Education and Training of the Blind" was read by Dr. J. M. Ritchie, M.A., Ph.D. The paper and discussion will be published in the *Journal* dated June 15th.

DR. MANN LECTURE.

MONDAY, APRIL 30th, 1928. MR. A. G. HUNTLEY, of the May Construction Co., Ltd., delivered the third of his course of three lectures on "Applied Architectural Acoustics."

On the motion of the Chairman, a vote of thanks was accorded to Mr. Huntley for his interesting and instructive course. The lectures will be published in the *Journal* during the summer recess.

BINDING COVERS FOR JOURNALS.

For the convenience of Fellows and others wishing to bind their annual volumes of the *Journal*, cloth covers can be supplied, post free, for 2s. each, on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.

DOMINIONS AND COLONIES SECTION.

TUESDAY, 28TH FEBRUARY.

EDWARD BRUCE ALEXANDER, ESQ., C.M.G., in the Chair.

THE CHAIRMAN said that wherever work in connection with the archæology of Ceylon was known the name of Sir Stephen Montagu Burrows was also known, and therefore he needed no introduction. It gave him great pleasure to be allowed to preside on the present occasion, because the lecturer was a distinguished member of the same service to which he himself had the privilege of belonging, the Ceylon Civil Service. Sir Montagu was at one time Assistant Government Agent at Mātale. When, after a lapse of some years, which it was inconvenient to specify, he had the good fortune to succeed to that post he was very happy to find that the memory of the lecturer was still green in the minds of the villagers and head men. In the wide range of his energetic activities, which his successors viewed with so much admiration, he had found time to continue his researches into the archæological treasures of Ceylon which he had begun when he was stationed in Anuradhapura. There was in the beautiful village of Nālande in the District of Mātale a very fine example of an ancient Hindoo Temple, known as the Gedige, which was restored by the lecturer and would always stand as a permanent monument of his labours in the field of archæology.

The following paper was then read :—

THE ANCIENT CIVILISATION OF CEYLON.

By SIR STEPHEN MONTAGU BURROWS, C.I.E.

The difficulties a stranger has in addressing a learned Society such as yours is to guess how much or how little his audience is likely to know already of his subject. His only possible device is to try and steer a middle course between the abstruse and the popular, which may possibly end in a quite unsatisfactory compromise. My only hope of telling you something new and interesting rests on two facts: that Ceylon is so much overshadowed by its enormous neighbour that its early history has to a large extent escaped public notice; and that when I went to the Bodleian Library to consult recent books on my subject, I found it had none, nor did the School of Oriental Studies in London possess complete copies of our Archæological Reports. And yet the so-called "Buried Cities" of Ceylon, with which my paper is mostly concerned, are, in their way, unique, and would possibly have afforded a better title than the one I have chosen, which may be open to the charge of being a misnomer. When I first had to do with Archæology in Ceylon, which is more years ago now than I care to remember, we looked on the civilisation we then began to unearth as very ancient indeed. Anything that dated from some 200 or 300 years B.C. seemed to merit that title to one who was taught in the schoolroom

that the world was created in 4004 B.C. How was it possible to guess that, forty years later, excavations at Mohenjo-Daro and Harappa would reveal an Indus civilisation to which Sir John Marshall at present assigns the date of B.C. 3,300—by no means unconnected, apparently, with a Sumerian civilisation of even earlier date revealed at Ur of the Chaldees? And how many centuries or millennia are we to allow for the gradual building up of those civilisations, and what previous attempt at development did they supplant? Truly the word "ancient" takes on a very different connotation so far as human culture is concerned; but at the same time much light is thrown upon the somewhat primitive attempts we used to make at the explanation of origins. We begin dimly to see that many parts of Asia and Central America anyhow attained to a very advanced state of culture thousands of years before we suspected it; that intercommunication was far more common than we had any idea of; and that we must be very careful in using, for instance, such a word as "aborigines" when we ought probably to be content with "decadents."

In getting a little nearer to my subject, it will of course be understood that when I use the word "history" I use it in the very widest sense; for of reliable history concerning early times in Ceylon there is none. Perhaps we have no right to be surprised, for Mr. Trevelyan, in his latest work, tells us that in spite of research of every possible kind we know absolutely nothing of the Saxon invasion of England; that, from the departure of the Romans to the arrival of St. Augustine, English history is a blank; and that we are left to make the best of shadowy figures such as Hengist and Horsa, and the hysterical lamentations of the melancholy Gildas. If that is the case with our own country at a very much later period, we can hardly expect more from the annals of an Eastern Island nearly 1,000 years ago. So we are left at the mercy of legends recorded in various chronicles, of which by far the most important is the well-known "Mahawansa," or genealogy of the great, which was begun by a Buddhist priest named Mahanamo in A.D. 460, and carried down by various monastic successors to the commencement of the British rule. But it will be observed that the author of this chronicle had apparently to trust to oral records in order to compile the history of the thousand years preceding his own date; and as some of our own Biblical records are held by certain writers to be under suspicion, although they are within 70 or 80 years of the date of the events they record, what shall we say of oral records that cover so vast a period? The other two ancient chronicles, the Dipavansa and the Rajawaliya—the former being older than the Mahawansa—give us very little more reliable information. The former does not profess to be a history of Ceylon at all, but of Buddhism, and therefore regards as immaterial the period preceding its introduction; and, though the Rajawaliya purports to write a history of the Sinhalese kings, its treatment of the first two centuries is extremely meagre, and its chronology largely unintelligible. It is true that a large number of inscriptions have been discovered and unearthed, but they again throw very little, if any, light on

early history. Dr. Edward Müller, who was appointed by Government to translate and report upon them, says, in the Preface to his book: "With regard to the contents of the inscriptions, I am bound to state that I have been greatly disappointed. Most of them are religious; they contain grants to different temples, but no historical information. The construction of tanks and other irrigation works is a subject continually repeated down to the 4th century, excepting only the cave inscriptions, which contain almost nothing but names." My friend Mr. Wickramasinghe, the Epigraphist to the Ceylon government, who is fortunately with us this evening, would probably claim for them a good deal more than this. He would probably say that linguistically the early cave inscriptions are of great importance owing to their close connection with the Asoka dialect; that, as a body of writings, they have enabled him to draw up a far more reliable chronology of the Sinhalese Kings than has been possible previously, which will shortly be published; that one at least—the long Mihintale inscription—contains a most interesting account of monastic life and regulations, with curious analogies to mediæval practices; and that another, the Vevalkatiya, gives important details of the administrative methods of the 10th and 11th centuries, and describes the system of itinerant Justices, not dissimilar to our English Justices in Eyre. But he would, I think, admit that all the inscriptions containing this kind of information are of a far later date than the period we are considering.

Nor do we get much help from outside sources of information. It would appear that Onesicritus, the chief pilot of a fleet sent by Alexander the Great to the Persian Gulf in the third century B.C., had at least heard of Ceylon. Megasthenes, the Greek ambassador to the Court of Chandragupta in the third century B.C., alludes to Ceylon, and calls its people *Palæogoni*. We learn from Pliny that in the reign of Claudius (A.D. 41-54) a freedman of Annius Plocamus, who had rented the customs of the Red Sea, while sailing round Arabia, was caught by the North winds and driven to Ceylon, where he landed at the port of Hippuros, presumably on the S.W. coast. He was taken to the king, who entertained him for six months, and afterwards sent an embassy to Rome. The earliest map of Ceylon we possess is that of Ptolemy, in the first century A.D. He calls the island *Taprobane*, and gives a very fair idea of its shape, and names the two chief cities as the Royal City of *Anurogrammon* (*Anuradhapura*) and the metropolis *Maagrammon*, possibly near *Polonnaruwa*.

None of these sources throw any real light on the questions we should like answered: Who the Sinhalese were? From whence and by what route did they come? Whom did they find in possession? There are, of course, a variety of legends to choose from, largely contradictory, and so full of exaggerations and poetic imagery as to be almost useless for practical purposes. All one can do is to draw such inferences as seem not improbable, without for one moment asserting that they are more than guesses. There is, of course, the celebrated Indian epic, the *Ramâyana*, which, as you know, narrates the

ravishing of Rama's wife, Sita, by Ravana, the demon King of Lanka, or Ceylon, and her recovery by Rama with the aid of Hanuman, the chief of the monkeys, after fierce fighting. But the curious thing is that this legend has never been current in Ceylon. The oldest chronicle, the *Dipawansa*, does not mention it, although certain definite places in Ceylon, such as Nuwara Eliya and Sita Eliya, occur in the legend. As the date of these epic encounters is quite problematical, we can only conclude that it points to a very early connection between Ceylon and India, and suggests that Ceylon at that time, instead of being inhabited by semi-bestial aborigines, must have been a fairly advanced community if its prince could carry through such a sporting episode. It is true that its people are called Demons; they are also called Snakes and Goblins in other legends; but such terms of endearment are not uncommon among contending races, and probably express contempt for a divergent form of religious worship.

Piecing together the legends current among the Sinhalese themselves, it seems clear that there was some form of Aryan invasion about 540 B.C. The leader was named Vijaya, and he apparently was the outcast son of a King of Lower Bengal; and as his grandmother had mated with a lion (*Singha*), the name of Sinhalese was bestowed upon, or adopted by, his party. He marries a princess of the land, Kuvéni, and afterwards throws her over in order to ally himself with the daughter of an Indian raja. The Indian ancestry of Vijaya is extremely vague, and appears to imply a connection between Bengal and Gujarat; and Mr. Codrington, whose "*Short History of Ceylon*" appeared in 1926, surmises that Vijaya may be a composite character, combining in his person two invasions, from the East and from the West; and this is quite as good a guess as any other.

This must necessarily seem a very sketchy account of the Aryan invasion of Ceylon, but it must be remembered that the neighbouring continent is no better off. Sir Thomas Holderness, in his excellent little volume on "*Peoples and Problems in India*," points out that there is no record of the pre-Aryan days of India, and that all we know of the Aryans themselves is from their hymns.

As to the people whom the Aryans found in possession, we are still more vague. They may have been, as the author of "*Ceylon*" in the *Encyclopædia Britannica* supposes, the ancestors of the present Veddahs; but it is reasonably plain that they were a well-organised and powerful community, and that it took the Aryans a long time to overcome them, whether by war or diplomacy. Hence these stories of marriages between the invaders and the indigenous women, and hence perhaps, too, the curious fact that the Veddahs are still spoken of in terms of respect even by the modern Sinhalese. Therefore, when Mr. Cave, in his well-known book "*The Buried Cities of Ceylon*," would have us think that the natives whom the Aryans met were in much the same state as the Veddahs are to-day, it may be suggested that he is drawing unwarrantable conclusions. The standard work on this interesting tribe is by Dr. and Mrs. Seligman, and they are, on the whole, of the opinion that the Veddahs are

survivors from the Stone Age, and have changed very little in the interval. It may be so ; it is possible that they led their quiet lives in remote jungles, undisturbed for an untold number of years, preserving a certain number of words and forms of speech from their own original dialect, which does not seem to be akin to other known dialects, but adopting at a very early period an archaic form of Sinhalese for purposes of occasional intercourse. But I am not inclined to disregard as entirely as the Seligmans do the attitude of the Sinhalese towards the Veddahs, and the honourable way in which they speak of them, and the absence of any dislike to intermarriage, and I have seen too much of the state of barbarism into which Sinhalese villagers can sink in remote spots to feel confident in classing any race as aboriginal.

We must pass rapidly over the period between the landing of Vijaya and his Aryans, and what may be called the dawn of actual history, for it is exceedingly obscure and legendary. It seems probable that the ruling family in Ceylon was connected more or less closely with Chandragupta, the powerful king of Magadha, who was supported by Seleucus Nicator, Alexander the Great's general, to whom the Indian province fell at the division of Alexander's empire. The grandson of Chandragupta was perhaps the most notable person that the Indian nation has yet produced—King Asoka. With his advent we are on firm ground ; for his Edicts, clearly carved on enduring rock, have no "Glozel" suspicions connected with them, and are most remarkable documents, well worth a study. If the extent of his Empire may be judged by the area which his inscriptions cover, he must have reigned practically over the whole of India, for they are found in the extreme North-West and in Mysore. His rule lasted some 38 years—from B.C. 270 to about 232, and during that period occurred the conversion of Ceylon to Buddhism. The Sinhalese chronicles are perfectly clear as to how that conversion was brought about ; but here you have to make your choice between two divergent opinions. Dr. Oldenberg and Mr. Vincent Smith will have nothing to do with the Sinhalese chronicles. They look upon them as worthless flights of poetical imagination, and the Professor prefers the supposition that Buddhism oozed in gradually from Southern India. On the other hand, Bishop Copleston, in his classical work on Buddhism, holds that these chronicles, in spite of their redundancy of imagery and their wild revel of incredible miracles, contain a very considerable substratum of truth. His highly-trained mind balances the probabilities with admirable justice ; and if a mere outsider may be allowed to express an opinion when such great authorities differ, I confess that in this matter I am on the side of the angels as represented by the Bishop ; and if this position may be allowed, it happily connects the island very closely with the great Asoka, and enhances the value of the Mahavansa. The discovery and translation of that unique chronicle we owe to George Turnour, of the Ceylon Civil Service, and his work coincided almost exactly with the labours of that great genius, James Prinsep, who was the first to decipher the edicts of Asoka, owing to a happy guess which proved to provide

the necessary key. When Turnour saw Prinsep's translations, it struck him at once that the King Asoka, whose energetic patronage of Buddhism was described in the Mahawansa, was extraordinarily similar, in sentiment and action, to the King Piyadasi, whose inscriptions Prinsep was translating. He guessed that both names referred to the same King, and was delighted to find this confirmed when he translated the Dipawansa some time later, and found the King called by both names.

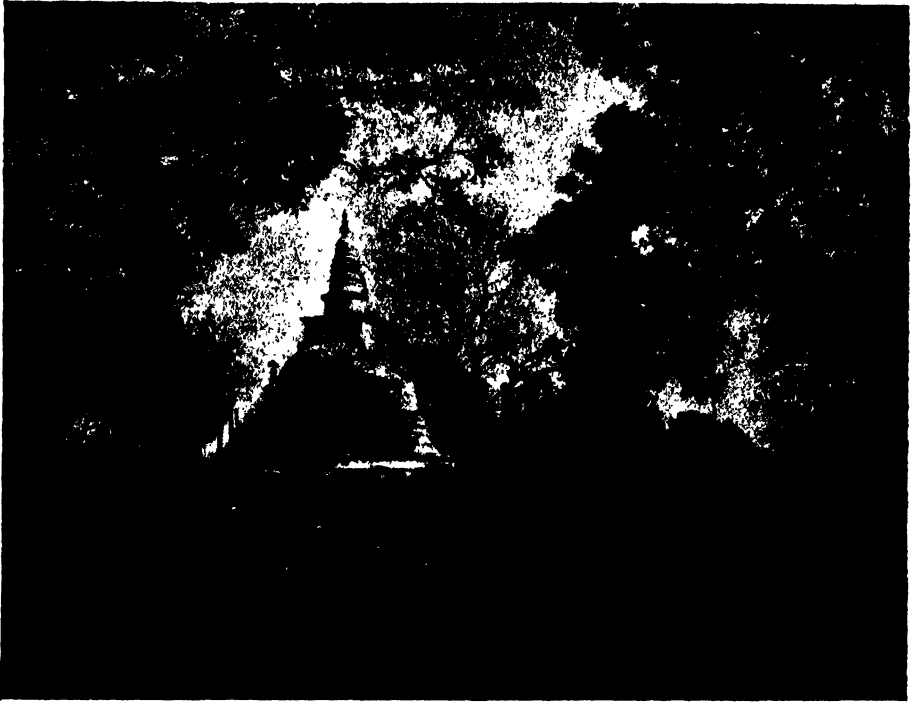


FIG. 1.—The Thuparama Dagoba, Anuradhapura.

The chronicles then inform us that the conversion of Ceylon to Buddhism was due to a visit from Mahinda, the son (or possibly the younger brother) of Asoka, one of the many missionaries whom that king sent out to countries far beyond the limit of India, and including Syria, Egypt, Africa, Macedonia and Epirus. The reigning monarch in Ceylon was Tissa, afterwards known as Dewanampiya, or "beloved of the gods"—the same title as that given to Asoka himself. The two kings were already friends and allies, and probably closely connected. The King's conversion, and that of his Court, was accomplished with remarkable rapidity; and, needless to say, was accompanied by many wonderful miracles. Nor did the ladies of the Court propose to be left out. The Princess Anula, with five hundred women in her train, demanded admission to the cult, and Mahinda's sister, Sanghamitta, was summoned from

India to initiate them. Then began the erection of the great monuments and monasteries, the remains of which still excite our wonder, at Anuradhapura, and which were nearly all erected in the Magamegha Park, the great Royal domain which King Tissa dedicated to the Community as his first act of piety and recognition. His second act was to mark for ever the sanctity of the hill Mihintale, about eight miles from the capital, where the king and the missionary first met, by the erection of dagobas, the provision of rock dwellings for hermits, and the erection of a remarkable stairway to the summit of some 1,800 granite blocks, which remain in fair order to the present day. But it was all-important that the new faith should be fortified by actual relics of the great teacher :

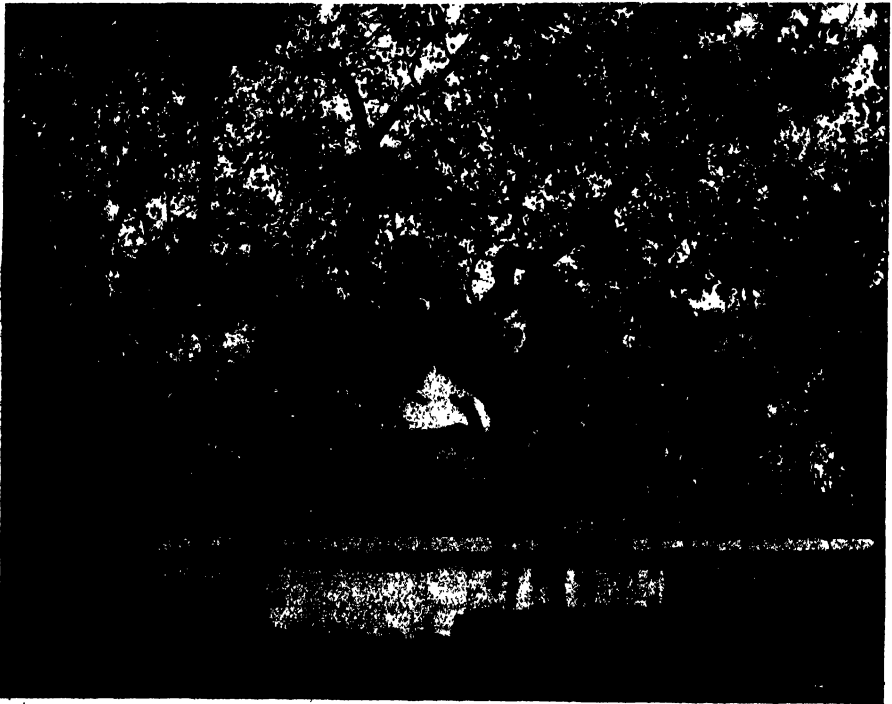


FIG. 2.—The sacred Bo-tree, Anuradhapura.

so, by happy co-operation between Asoka and the Prince of the Lower gods, the collarbone of Buddha was obtained and enshrined in the beautiful Thuparama Dagoba (Fig. 1.), still existing as the most ancient building in India, and the most graceful monument that Anuradhapura has to show. To this was added an equally venerable relic—an actual branch from the Bo-tree under which the Buddha attained Nirvana at Budhgaya. Needless to say that, to save King Asoka from the indecency of cutting into the tree himself, the branch was obliging enough to detach itself, and even to provide its own

transport part of the way, and to plant itself in the golden vase prepared for it. There it stands (Fig. 2) to this day, 2,215 years old, and claiming to be the oldest historical tree in the world ; though the latest writer on Ceylon, Major Enriquez, fears that its days are almost numbered. It is walled round with terraces, and only two boughs remain, neither of them robust ; but it is still the main object of pilgrimages on festival nights, and a leaf from it (not always genuine) is a very precious souvenir.

This is not a guide book, nor would time allow me to take you in detail through the ruins of Anuradhapura. All I can do is to call your attention to a very few of the structures erected by Tissa and his pious successors, so as to give you some slight idea of the scale on which they worked. The most promi-



FIG. 3.—The Abhayagiriya Dagoba, Anuradhapura.

nent features are the three vast Dagobas, the Ruanweli, built by King Dutugemunu about B.C. 160, to receive various relics of the Buddha ; the Jetavanarama, built about 89 B.C., on the site where Buddha is reputed to have stayed during his visit to Ceylon ; and the Abhayagiriya (Fig. 3), belonging to the third century A.D. All are hemispherical in form, crowned with a square platform and a monolith, but of course their size has been greatly reduced by the tearing effect of the enormous trees that have grown upon them for many centuries, and the deluging rain of the tropics. All are of solid brickwork, and

the description which Emerson Tennent gives of the Abhayagiriya, though quoted in all the books, is worth repeating. He says (in 1860), "Even with the facilities which modern invention supplies for economising labour, the building of such a mass would at present occupy 500 bricklayers from six to seven years. The materials are sufficient to raise 8,000 houses, each with twenty feet frontage, and these would form thirty streets half a mile in length. They would construct a town the size of Ipswich or Coventry; they would line an ordinary tunnel twenty miles long; or form a wall one foot thick and ten feet high reaching from London to Edinburgh." These are only the three



FIG. 4.—Ruins of the Brazen Palace, Anuradhapura.

largest among the many other dagobas, but they must have been eclipsed in glory by the great Brazen Palace (Fig. 4) erected in the 2nd century B.C. on a plan brought straight from heaven, reputed to have been nine stories high, and to have contained 1,000 dormitories for priests, and other apartments. The roof was of sheet copper; the walls were embellished with gems; in the centre was an ivory throne, and above all glittered the imperial "Chatta," the white canopy of dominion. It was naturally sacked times without number, but its foundation, or lower story, still remains, consisting of 1,600 monolithic granite pillars, standing about twelve feet out of the ground, and arranged in lines of forty each way.

The remains of other religious buildings (Fig. 5), platforms, stone pillars, statues, bathing tanks and huge monolithic stone "canoes," (possibly for the feeding of priests or pilgrims) are innumerable; and, though the Archæological Survey has been at work upon it since 1886, we are not, so far as I am aware, able to say exactly how large an area the city occupied. And it must be remembered that we are talking of the religious part of the city only. It is not even certain where the King's Palace was; possibly it was a collection of miscellaneous buildings, not of stone, or it may have been so obvious an object for attack and pillage during the many invasions that it has entirely disappeared. Still



FIG. 5.—Steps and "Moonstone" of a temple in position, Anuradhapura.

less do we know where the ordinary people lived. There are some signs of dwellings of a later period, and we have some notion as to the directions of the various roads, and perhaps we can expect no more, for no doubt the dwellings were constructed of as flimsy materials as the native houses of modern times; and those of us who have not seen the jungle forces at work, but have read Kipling's striking story, "The Letting in of the Jungle," will understand that their survival value was not large. The same thing applies to pre-Asokan architecture. It seems probable that stone and brick building came in with the Asokan period, but the existence of the well-known "post and rail"

enclosures at Sanchi and Barhut, at Anuradhapura and Polonnaruwa, shows how closely early stone erections approximated to wooden originals; and climate, jungle and insects have combined to deprive us of all knowledge of the timber architecture of preceding ages.

Perhaps enough has been said, in this very inadequate sketch, to show that Anuradhapura was a vast, and a very notable city. Two travellers visited it, very different in kind, with an interval of 1,200 years between them. Robert Knox, a merchant seaman, was captured at Trincomalee in 1659, when he was ashore getting water for his ship. He passed twenty years in captivity, and eventually escaped, after breathless adventures, to a Dutch port. He passed by Anuradhapura on his perilous journey, and saw it as a desolate world of hewn stone pillars. The Chinese traveller, Fa Hien, in the 4th century A.D., passed two years in the city at the zenith of its glory. Nothing surprises one more, in his account of his travels, than the possibilities of travel at that period. He was an "illustrious master of the Law," and finding that certain Buddhist scriptures were not obtainable in China, he set out to get copies of them, much as one might set out nowadays to see a first-folio Shakespeare in America (where most of them are). He describes the concourse of merchants in the city, living in houses stately and beautiful; and the excellent order in which the streets and lanes were kept. There were large preaching halls at the heads of the four principal streets, whither flocked the priests and the people three times a month to hear the law. He was told that in the kingdom there were 60,000 monks who got their food from the common stores, while the king fed some 5,000 or 6,000 more in the city. He describes the magnificent cremation of an arhat, or holyman, who had attained semi-divine attributes; he got copies of all the books he wanted, and set sail for China again in a merchant ship that held 200 people.

But there are one or two difficult points to consider. The choice of such a site for a capital city—Canterbury and London combined—was a curious one. The country round it is perfectly flat, and there are no natural means of defence. Whether it was really founded by a son of one of the early kings named Anuradha, or was called after a constellation, or was marked by a miraculous event, is quite uncertain. It may have been surrounded by a wall (of which there is no trace); certainly in the sixth century a Chinese author reports that the Ceylon cities were encompassed by brick walls; or the king may have kept a large enough army to ensure its safety; or the relations between Ceylon and India may have been so friendly, and the relationships so close during the early period, that invasion was not likely. Nor was there any natural water-supply to account for the site. The city is situated in the dry zone, with no mountains near to intercept the trade winds and condense their vapour. Droughts are frequent, and the soil is poor; therefore, the early construction of large reservoirs was a prime necessity, and we are told that the earliest tank at Anuradhapura was made by Vijaya's successor in 505 B.C.

—the Basawak Kulama ; and this was supplemented by two other large reservoirs at later periods. In Emerson Tennent's day they were pestiferous swamps, but have been restored by the British Government, and are as effective now as they were 2,400 years ago. But even this provision proved inadequate as the city grew and the demands of cultivation increased ; and in the fourth century A.D. King Dhatu Sen conceived the brilliant idea of bringing a permanent supply to the town from the nearest hills. He constructed a vast tank called Kala Balalu Wewa to catch the flow of two streams that run from the northern spurs of the hill district. It has an area of seven square miles, with a contour of thirty miles, and an enormous bund at the Western outlet, six miles long, with a breadth of twenty feet at the top and an average height of sixty feet, formed of huge blocks of stone and earthwork. From it he ran a canal to Anuradhapura, fifty-four miles in length ; and when both these works were restored by government (which took three years and over half a million rupees) there was very little fault to find with the trace of the canal. This work by itself is not a bad tribute to the state of civilisation and engineering skill that the island attained to. There can be little doubt that the Sinhalese learnt the art from their Indian neighbours. Even as far back as the Ramayana, "diggers of canals" are mentioned. The Mahawansa ascribes the early tanks of the fourth century B.C. to a Brahman engineer, and an inscription at Mihintale in the second century B.C. gives to the Malabars the credit of inaugurating the system of water supply.

There is a further question on which only a limited amount of light can be thrown : how was it that Buddhism spread with such phenomenal rapidity— if the accounts may be trusted—through India and Ceylon, with lasting effects as far as Ceylon was concerned, though only ephemeral in India ? The answer may be that we make too much of the change ; that Buddhism was a not unnatural offshoot from the parent Brahmanism ; that the Muhammadan invasion had not then taken place, and that therefore the rules of caste, which the shock of that invasion did so much to solidify, were not so rigid ; and that Asoka's own religious views were peculiarly wide, as in his Edicts he enjoins the duty of almsgiving to Brahman as well as to Buddhist ascetics, sees good in all creeds, and lays it down that personal adherence to one's own creed is the chief thing.

I confess the explanation appears to me inadequate, as several of Asoka's enactments were distinctly revolutionary ; and yet there is no sign of any opposition whatever, either in India or Ceylon. Its rapid spread is far more remarkable than that of Christianity or Muhammadanism, for it is a creed by no means adapted to the ordinary intercourse of life, or the mind of the common man. Historical parallels are perhaps a dangerous form of amusement, but it is just possible that there may be many points in common between the sudden success of Wesleyanism and that of Buddhism ; while if we may stretch a further point, and compare Asoka and Constantine, it is probable that Asoka's

part was far more prominent and convinced, and that his actions and edicts were the outcome of a fervid missionary spirit, as contrasted with the well-balanced political considerations that eventually weighed with Constantine.

We have, then, a fair amount of material wherewith to form a sort of picture of this vast Buddhist city, teeming with busy life, mercantile and religious, developing an architecture akin to the Indian, but with its own special characteristics, constantly liable to invasion from the continent, but managing with short intervals of misfortune to maintain its independence and position as the capital of the Sinhalese race and the most important city of Buddhism for nearly 1,000 years. But the kings of the great Solar Dynasty gradually

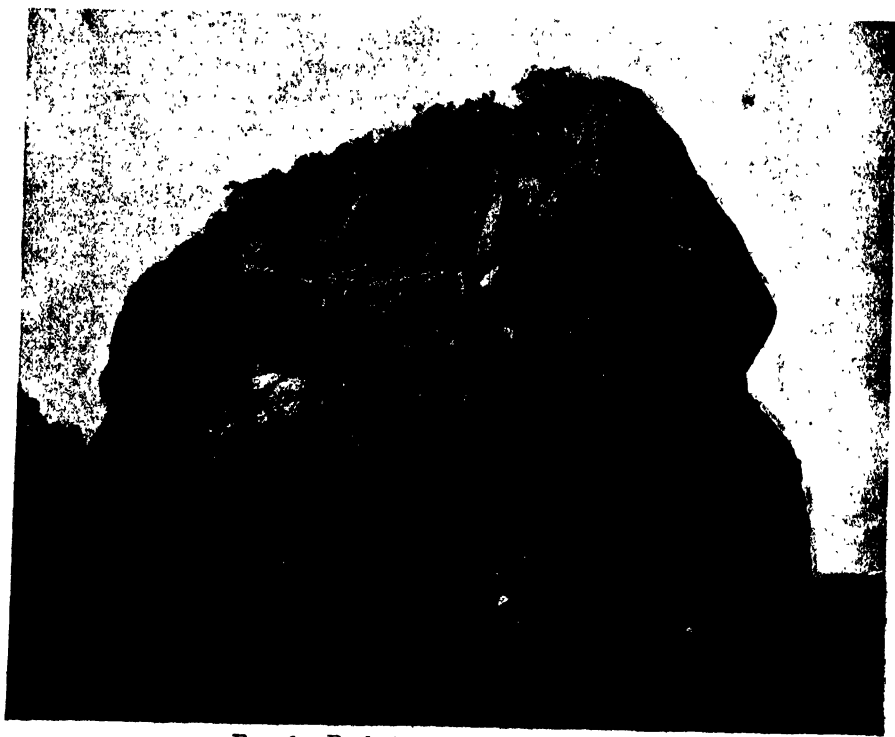


FIG. 6.—Rock fortress of Sigiriya, Matale.

declined in power and capacity, while the attacks of the Tamils from India became more persistent; and in the eighth century A.D. Anuradhapura was abandoned, and a new capital founded at Polonnaruwa. There had been a temporary abandonment of the capital in the 5th century A.D., when a parricide king, named Kasyapa, who had brutally walled up his father alive and was afraid of the vengeance of his outraged subjects, adopted the curious Rock of Sigiriya (Fig. 6) as his residence. Tradition assigns the whole of the work done at Sigiriya to King Kasyapa, but this is most unlikely, for the buildings

and other constructions are far too extensive to have been the work of one king in a disturbed and brief reign ; but of the earlier and later history of the fortress-palace we are curiously ignorant. The rock is over 400 feet high, rising abruptly from the plain with precipitous sides and a fairly flat top. To build on the summit a large and commodious palace most ingeniously arranged, and to live in it, demanded facility of access ; and the construction of a broad stairway external to the rock and circling round it was an engineering feat unparalleled, at least in Ceylon. The stairway had a flanking wall on its outer side ten feet high, coated with chunam (a preparation of lime and white of egg) ; and portions of the wall and its covering are as perfect now as when they were made. In a pocket high up the rock, and equally inaccessible from the stairway or the summit, is a gallery of female portraits, seventeen in number, and evidently a procession to a temple, as all are carrying flowers. They are partly ladies of rank and partly serving maids, and the paintings have many points in common with those at Ajanta, and those at Bagh, discovered by my lamented friend Colonel Luard ; copies of which were recently on view at the British Museum. How the painters got to this pocket is an insoluble problem. We found it a difficult job enough, with all modern appliances, for the rock bellies out above and below the entrance to the pocket, and I was seldom more relieved than when I found myself safely inside this aerial Burlington House. The colours are remarkably fresh, after 1,500 years' exposure to the weather, but the entire omission of blue is difficult to account for, as it is freely used at Ajanta.

Time forbids that I should dwell at any length on the other great "buried city," Polonnarua. Obviously it had long been a royal residence, as its principal tank was constructed in the fourth century A.D., and it was the capital of the lessened kingdom for rather less than 500 years. The ruins are only less striking than, and almost as extensive as, those at Anuradhapura, but their identification is very uncertain, and there is a much stronger Hindu element in the architecture, mainly Vishnuvite, with a tendency to Snake worship. When I began excavations here, I was astonished to dig up very clear remains of a stone "post and rail" enclosure, of the Sandhi type, at a building which apparently belongs to the 12th century ; a striking proof of the survival of this essentially wooden conception. Perhaps the most notable shrine is the Gal Vihara, as it contains three heroic figures carved out of the same abrupt boulder of solid granite ; a sedent Buddha fifteen feet high, an upright figure, twenty-three inches high, possibly representing Ananda, the favourite disciple, and a reclining Buddha, forty-six inches in length, a very striking piece of statuary.

Polonnarua was abandoned about the middle of the thirteenth century, and the seat of government was transferred from place to place, till at last, in 1552, news was brought to the king that a ship had anchored near Colombo containing a race of men "surprisingly white and beautiful, wearing boots and

hats of iron, eating a white stone and drinking blood, and having guns which could break a castle of marble." So, with the coming of the Portuguese, the ancient civilisation closes.

In comparison with excavations elsewhere, it is of course disappointing that in these "buried cities" of Ceylon we have found so little that throws light on the characteristics, the dress, the ornaments, the ordinary life of the ancient inhabitants. That of course is due to two causes. Nearly all the "finds" of this nature elsewhere have been due to the burial customs of the people of that locality. Where Kings made tombs that were to last for ever, and desired to take with them to the next world a large selection of their most valued possessions, and a large following of their most valued servants, we have some chance of stepping right back into the life of the time. Nothing of the sort can ever be expected in a land where the Buddhist religion prevailed. The doctrine of immediate rebirth was so essential a part of Buddhism that it prevented any great value being attached to the human body. Secondly, these ruins have been exposed for many hundreds of years to the activities of treasure-hunters—a sport that seems to appeal to all peoples in all climes, much to the detriment of archæology, and particularly of inscriptions; for a stone with writing on it is popularly supposed to cover hidden treasure, which can best be discovered by splitting the stone by means of fire. We must be content with what is left; and the end of my story leaves me full of admiration for the great civilisations that preceded European influences, and particularly for those pre-Buddhist Aryan adventurers who, I suspect, have had scant justice done them by the obviously partial historians of the new religion, and were possibly the joyous, large-hearted authors and begetters of a system of local self-government, appropriate methods of cultivation and bold experiments in engineering which lasted for many centuries.

DISCUSSION.

MR. DON M. DE ZILVA WICKREMasinghe (London School of Oriental Studies) said he was sure the audience would agree with him when he said how gratified they were with the account that had been given of the ancient civilisation of Ceylon, the premier Crown Colony of the British Empire, delivered in such a breezy and refreshing style by a scholar who was a brilliant member of that band of Civil Servants who had done so much for the welfare of Ceylon. The lecturer was one of the pioneers, living in a hot steamy climate laden with malaria, who, in the midst of his official duties found time to explore the ruins. That was mentioned in the lecture, but the lecturer had scrupulously avoided speaking about himself. It was he who rescued the ruins from oblivion. He had created by his writings and reports a great interest in the minds of the Ceylon public. He had identified some of the ruins and his identification held good to-day. He (the speaker) had had the pleasure of working with his erstwhile chief, Mr. H. C. P. Bell, for two years, and it was that officer who gave him his first interest in research work and trained him in the hard school of practical work in the backwoods of Anuradhapura. He could remember

many interesting incidents that happened to him during that time. In one instance he was looked upon suspiciously by villagers who thought he was a magician, and he encouraged them in that belief because sometimes he was able to frighten them into showing him where the inscriptions could be found by promising that if they did not, he would bring all sorts of evil upon them. On another occasion while reading inscriptions he had looked into a cave and noticed that in the dark there was lying a she bear with her young!

In his own humble way before severing his connection with the Ceylon Archaeological Department, he dedicated his second volume of *Epigraphia Zeylanica* to Mr. Bell, and he should certainly say that Ceylon ought to found either a Fellowship or a Chair, or a Prize for Archaeological Research to perpetuate the name of Mr. Bell, and he hoped that this would be done.

Looking into the early description of places as found in Tamil and Sinhalese books one could form quite a good idea of the really advanced state of civilisation in those early times. There was the question of whether the people were Tamils or Pariahs or what. One of the theories was that the Tamils came into the country before the Aryans. Historians had traced Tamil emigration from the north-west to the south, and later the Aryans came and drove the Dravidians south. All the ideas put forward did not seem quite satisfactory. Previous to Tamil times the country was inhabited and had a tolerably high civilisation and culture. His own idea was that the whole population of India and Ceylon were really more or less mixed; in fact strictly speaking there was no nation in the world that was absolutely pure in breed. With regard to the Vijayan invasion, he believed that that invasion was probably an invasion of Aryan culture. The later kings treated the early aborigines more or less on an equality. In Ceylon, just as in India, stone architecture could be found in perfection, but there was hardly any stone architecture or sculpture that could be ascribed to a period before Asoka, the buildings of that time being in wood. He could not imagine how within fifty years the clever carver in wood was able to take living rock and carve out statues. The shortness of the time was a problem no one had yet solved. Whether they brought in teachers to instruct the workers in Ceylon he did not know. With regard to the cultural side, the lecturer had pointed out how well organised were the monastic institutions. He had found an inscription which showed that there were maternity and general hospitals, and in the case of some of the hospitals it was interesting to note that in certain contingencies, especially in the case of war, it was usual for ladies of good family to become nurses, as was the custom in Europe to-day. There were even hospitals for horses.

PROFESSOR C. G. SELIGMAN, M.D., F.R.C.P., F.R.S. (Professor of Ethnology, University of London) said he had enjoyed the paper very much. He had seen a great deal of the country mentioned when he was spending some time in the jungles, and would certainly never forget his first view of Polannarua across a wonderful sheet of water in which floated pink and red lotuses. He should like to say something about the Veddahs. There had been a tendency to look on them as an isolated people, but that was not so; they were just the Ceylon representatives of the long-headed, rather dark jungle men, hunters that could be found in the South Indian jungles and in the jungles of the Malay Peninsula. Even if there were not Veddahs in Ceylon it would be expected that the original inhabitants of the island had been people of that type.

A rather remote relative to the Veddah might be the Australian black-fellow, and he was certainly grouped in the same section of humanity from the anthropo-

logical point of view. The Sinhalese were quite a different race. He took it that what happened in Ceylon was that the more civilised invaders came in from the North, and he did not see any reason why they should not have come from the plains of the Ganges and effected a settlement and gradually encroached on the natives. There was always a fringe of contact. The Veddahs might become gradually influenced by the Sinhalese, and there was evidence of such a contact zone in some of the Sinhalese stories. There was a story of a 16th century man called "Panikki the Veddah," who was a person of considerable importance. He lived in one of the jungle districts and traced his descent from the Veddahs, but he was a fairly civilised individual. The process of narrowing down the area where the actual Veddahs lived went on for centuries, and that was the reason why so many of the up country Sinhalese were proud to trace their descent from the Veddahs. He had received a good deal of help from an old Sinhalese gentleman who was a landed proprietor, and he was proud of having Veddah blood, and when he got into the Veddah country there was a distinct feeling that the Veddahs regarded him as a relative of theirs. Twenty years ago, when Mrs. Seligman and himself went to Ceylon, there were four or five Veddah families who seemed to lead a pure Veddah life, and it was from those families that they were able to obtain the information with regard to their ceremonies. He had never been able to form a clear notion of the process by which the Sinhalese system of relationship became adopted by the Veddahs. With regard to the archæology of the Veddahs, in excavating some caves they had come across some rough stone implements. It was quite likely that the jungle people of Ceylon were in the Stone Age at quite a recent period, say two thousand years ago. There was at one time a great wave of Buddhist asceticism coming in with a tendency for hermits to retire into the jungle, and there was evidence all over the country of that fact. The drip ledges over caves often had inscriptions beneath them, and it frequently happened that caves once inhabited by anchorites came to be occupied afterwards by Veddahs. That went on for a long time and now the caves in the Veddah country were scored with inscriptions of that sort. There were remains of stone carvings of the period in the Veddah caves, and he would exhibit a slide which showed stone steps which were carved by the old Sinhalese. The thesis he should put forward was that there was a slow narrowing down of the Veddah country, the process being complete at the present day. The Veddahs were very bad shots with the bow and arrow, but they were good stalkers and never loosed off the arrow until they were within a few paces of their quarry. The arrows had knifelike edges and it was not possible to miss a deer at that distance. Their mixing with the incoming people on equal terms had a good parallel in Southern India. Even at the present day there is an instance of a Rajah when installed being marked on the forehead with the blood of a member of the local jungle-tribe.

THE CHAIRMAN said he was not an authority on archæology and not competent, therefore, to criticise the very interesting lecture which had been given. That paper had already had one good result, because it carried him that morning to the publishers, Messrs. Macmillan, from whom he purchased a copy of Codrington's *Short History of Ceylon*, and he hoped that many who were present would follow his example. Mr. Codrington was another member of the Civil Service and one of the highest authorities on all historical questions relating to the customs of Ceylon.

MAJOR SIR HUMPHREY LEGGETT, R.E., D.S.O. (Chairman, Dominions and Colonies Section), in moving the thanks of the Society to the Chairman and to the lecturer

for his extraordinarily interesting lecture, said that at the time when the marvellous Sinhalese architecture was at its height Buddhism was also in its purest form. What was it? The lecturer had compared it to Wesleyanism and this was a very suggestive comparison, but he ventured to note with regard to the history of Buddhism that the original Hinduism, which went back some thousands of years, was still persistent, and as epoch succeeded epoch, at certain times obtained the upper hand and the quality of aesthetic expression deteriorated during those periods.

The vote of thanks was carried unanimously, and the meeting terminated.

NOTES ON BOOKS.

PREPARATION OF SCIENTIFIC AND TECHNICAL PAPERS. By Sam F. Trelease, Associate Professor of Botany in Columbia University, and Emma Sarepta Yule, Head of Department of English in the College of Agriculture of the University of the Philippines. London: Baillière, Tindall and Cox. 7s. net.

It is not difficult to see that the task of a scientific writer is threefold; he must amass a collection of relevant material, by experiment, by reference to previous publications, and by abstract thought; he must select from this mass, and arrange his selection in such a way as to convey the desired impression to the reader; and, finally, he must produce such a manuscript as will give in unmistakable terms the necessary instructions to the printer.

All these aspects of the writer's problem are considered in this little hand-book, though it has naturally not been possible to include very much under the first of the three headings. The authors have had a wide experience in the reading of students' manuscripts, and all their suggestions are worthy of consideration, though on many points it is only to be expected that individual opinions will vary.

It is pointed out very justly that, while the printer cannot be asked to correct any kind of actual error, scientific authors have nevertheless a right to assume that their publisher will employ compositors with some special skill in setting up technical matter.

Many cases occur, however, in which it is not easy to fix the relative responsibilities of author and compositor. It is unfortunate, for example, that the first numeral is denoted in typescript by the twelfth letter of the alphabet, so that it is possible for a compositor to set up wrongly the chemical symbol of Cl for the element chlorine; but not every chemical writer would agree that it is his duty, as the present authors maintain, to mark his typescript in such a manner as to make this error impossible.

Again, it is a little insufficient to remark with reference to algebraic symbols and equations, that these "should be italicized," having just previously explained the usual convention for italics. Unfortunately this convention, of a horizontal line under the letters, is required in mathematics for quite different purposes; and it is both obvious and notorious that for mathematical work there must be an *ad hoc* understanding between author and compositor if complete chaos is to be avoided.

On the whole, however, the advice given is sound and clear, and the book deserves the attention of all who have occasion to publish technical papers.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, MAY 7. Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Annual General Meeting.

Engineers, Society of, at Burlington House, W. 6 p.m. Mr. J. N. Hare Duke, "Technical Education in Relation to Industrial Development in India."

Geographical Society, at the Æolian Hall, 135, New Bond Street, W. 8 p.m. Lt.-Col. L. N. F. I. King and Capt. E. H. M. Clifford, "The Jubaland Boundary."

Surveyors' Institution, 12, Great George Street, S.W. 8 p.m. Discussion on the Report of the Royal Commission on Land Drainage in England and Wales.

Victoria Institute, at the Central Hall, Westminster, S.W. 4.30 p.m. Pastor R. Saillens, D.D., "Protestantism and Rationalism in France."

University of London, at King's College, Strand, W.C. 5.30 p.m. The Rev. Dr. R. S. Franks, "The Metaphysical Justification of Religious Experience." (Lecture I.)

5.30 p.m. Dr. Eileen E. Power, "The Domestic Letter Writers."

5.30 p.m. Mr. H. Wickham Steed, "The Prelude to the War." (Lecture I.)

At University College, Gower Street, W.C. 2 p.m. Prof. H. E. Butler, "Two Ancient Love Stories in Epic."

5 p.m. Dr. G. E. Coghill, "Anatomy and the Problem of Behaviour." (Lecture I.)

5 p.m. Prof. Dr. G. Dawes Hicks, "Ruskin's Theory of Art." (Lecture I.)

TUESDAY, MAY 8. Anthropological Institute, 52, Upper Bedford Place, W.C. 8.30 p.m. Mr. E. Torday, "Dualism in Western Bantu-Religious and Social Organisation."

Civil Engineers, Institution of, Great George Street, S.W. p.m. Annual General Meeting.

Colonial Institute, at the Hotel Victoria, Northumberland Avenue, W.C. 8.30 p.m.

Marine Engineers, Institute of, 85-88 Minories, E. 6.30 p.m. Mr. A. T. Ridout, "A Non-chemical Method for the Prevention of Scale Accumulation in Boilers, Diesel-Jackets, and Water Circulating Systems in general."

Metals, Institute of, at the Institution of Mechanical Engineers, Storey's Gate, S.W. 8 p.m. Prof. Dr. C. H. Desch, "The Chemical Properties of Crystals."

Petroleum Technologists, Institution of, at the Royal Society of Arts, Adelphi, W.C. 5.30 p.m. Messrs. H. S. Rowell and D. Finlayson, "Experiments in Viscometry."

Quekett Microscopical Club, 11, Chandos Street, W. 7.30 p.m. Dr. E. J. Salisbury, "Stomata."

University of London, at University College, Gower Street, W.C. 5 p.m. Dr. G. E. Coghill, "Anatomy and the Problem of Behaviour." (Lecture II.) 5.30 p.m. Mr. Charles Aitken, "Rossetti, the Painter."

WEDNESDAY, MAY 9. Archaeological Institute, at Burlington House, W. 5 p.m. Mrs. Rose-Troup, "The Personality of Bishop Grandisson."

Fuel, Institute of, at Burlington House, W. 6 p.m. Mr. A. J. T. Taylor, "The Engineer in Industry."

Geological Society, Burlington House, W. 5.30 p.m. Mr. W. B. R. King, "The Geology of the District around Meifod (Montgomeryshire)."

University of London, at King's College, Strand, W.C. 5.30 p.m. Dr. J. A. Berens de Haan, "Animal Psychology for Biologists." (Lecture II.)

At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Dr. Hubert Hall, "Some Common Factors in the Economic and Social Development of England in Mediaeval and post-Mediaeval Times." (Lecture II.)

THURSDAY, MAY 10. Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m. Mr. B. M. Wallis, "Design and Construction of Modern Rigid Airships."

Chemical Society, at the Royal Institution, 21, Albemarle Street, W. 5.30 p.m. Sir James Walker, D.Sc., F.R.S., Arrhenius Memorial Lecture.

Historical Society, 22, Russell Square, W.C. 5 p.m. Mr. H. G. Richardson, "The Origins of Parliament."

Oil and Colour Chemists' Association, at 8, St. Martin's Place, W.C. 7.30 p.m. Annual General Meeting. Dr. H. Hepworth, "Nitrocellulose Lacquers." Demonstration of Analytic Quartz Lamp.

Royal Society, Burlington House, W. 4.30 p.m.

University of London, at King's College, Strand, W.C. 5.30 p.m. Sir Charles Holmes, "Rossetti as an Artist."

Mr. Alfred Noyes, "Rossetti as a Poet."

5.30 p.m. Prof. J. O. Thomson, "Problems of Ancient Geography."

At University College Gower Street, W.C. 5 p.m. Dr. G. E. Coghill, "Anatomy and the Problem of Behaviour." (Lecture III.)

5.30 p.m. Prof. Halvdan Koht, "Henrik Ibsen." (Lecture I.)

FRIDAY, MAY 11. Astronomical Society, Burlington House, W. 5 p.m.

Chemical Industry Conference, at Les Gobelins Restaurant, 1, Heddon Street, W. 6 p.m. Annual Meeting of Chemical Engineering Group (Society of Chemical Industry) and Institution of Chemical Engineers.

8.30 p.m. Mr. Francis H. Carr, "Some Chemical Engineering Aspects of the Fine Chemical Industry."

Malacological Society, at Burlington House, W. 6 p.m.

Physical Society, at the Imperial College of Science South Kensington, S.W. 5 p.m. 1. Dr. E. G. Richardson, "The Amplitude of Sound Waves in Resonators." 2. Mr. R. E. Clay, "The Focus of a Gas-filled X-Ray Tube." Demonstration of an Electric Harmonic Analyser by Dr. R. Thornton Coe.

Royal Institution, 21, Albemarle Street, W. 9 p.m. Prof. Doris L. MacKinnon, D.Sc., "Life's Unsuspected Partnerships."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. Julian Krzyzanowski, "Polish Culture in the Middle Ages." (Lecture I.)

At King's College, Strand, W.C. 5.30 p.m. Dr. J. A. Berens de Haan, "Animal Psychology for Biologists." (Lecture III.)

5.30 p.m. Prof. Denis Saurat, "Contemporary Provençal Poets" (in French). (Lecture II.)

At University College, Gower Street, W.C. 5.30 p.m. The Rt. Hon. Sir Samuel Hoare, "The Value of Aviation to the British Empire."

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

NEXT WEEK.

WEDNESDAY, MAY 16th, at 8 p.m. (Ordinary Meeting.) W. WORBY BEAUMONT, M.Inst.C.E., "Modern Motor Car Design: Some Criticisms and Suggestions." ALAN A. CAMPBELL SWINTON, F.R.S., a Vice-President of the Society, will preside.

SWINEY PRIZE.

The Council have to give notice that the next award of the Swiney prize will be in January, 1929, the eighty-fifth anniversary of the testator's death. Dr. Swiney died in 1844, and in his will he left the sum of £5,000 Consols to the Royal Society of Arts, for the purpose of presenting a prize, on every fifth anniversary of his death, to the author of the best published work on Jurisprudence. The prize is a cup, value £100, and money to the same amount.

The award is made jointly by the Royal Society of Arts and the Royal College of Physicians. In accordance with the arrangement with the Royal College of Physicians, the award next year will be for a work on Medical Jurisprudence.

Any person desiring to submit a work in competition, or to recommend any work for the consideration of the judges, should do so by letter, addressed to the Secretary of the Society, not later than November 30th, 1928.

A list of former recipients of the prize was given in the *Journal* dated March 23rd.

TWENTIETH ORDINARY MEETING.

WEDNESDAY, MAY 2nd, 1928. THE HON. SIR CHARLES A. PARSONS, O.M., K.C.B., LL.D., D.Sc., F.R.S., in the Chair.

A paper on "Standardisation in Apparatus for Science Teaching" was read by MR. WILLIAM TAYLOR, O.B.E., of Messrs. Taylor, Taylor and Hobson.

The paper and discussion will be published in the *Journal* dated June 22nd.

PROCEEDINGS OF THE SOCIETY.

INDIAN SECTION.

FRIDAY, MARCH 9TH, 1928.

COLONEL THE MASTER OF SEMPILL in the Chair.

THE CHAIRMAN said the subject of the paper was of very great interest and importance to the future of the commercial air route system of the British Empire. He recalled that in 1910 Major Juillerot, who now occupied an important position in the aviation section of Messrs. Vickers, was the first person to make successful flights in India with an aeroplane. On January 2nd, 1911, Major Juillerot, flying a Bristol "Box-Kite," ascended from the racecourse at Calcutta with Lieutenant Brancker (now Air Vice-Marshal Sir Sefton Brancker) as his passenger. There had previously been several attempts at mechanical flight, which had been unsuccessful. In February, 1911, following on that successful flight, Major Juillerot received an invitation from Sir Douglas Haig, then Chief of the Staff in India, to attend the manœuvres in the Deccan. He attended those manœuvres with the same machine, with Lieutenant Brancker as his passenger, and demonstrated for the first time in India the value of aircraft in military operations.

The lecturer, Colonel Edwards, had also served for many years in India, and in 1911 made an attempt to join the Air Service which was then being formed. This, due to the unsympathetic attitude of the Indian military authorities, was unsuccessful. He therefore failed to be on the first course of the Central Flying School, which was the course on which many of the best known figures in aviation to-day, Sir Hugh Trenchard, among others, began their aeronautical careers. For the last fourteen or fifteen years, however, Col. Edwards had been intimately connected with aviation, and at the present moment occupied the position of Technical Adviser to the Department of Civil Aviation. He had occupied that position since 1922, and during those years the foundations of our civil air communication system had been laid, largely as a result of his advice. Prior to that, in 1919, Col. Edwards had been to India on behalf of the Handley-Page Transport Company, and took with him a number of pilots, mechanics, and three Handley-Page aeroplanes. On that occasion he was able to demonstrate to the people in India some of the advantages to be gained from air transport, but owing to the fact that he was there rather too early, and that the Indian authorities were not quite educated up to the value of air transport, for economic reasons he had had to close down the experimental service he was running. He then returned to England to occupy the distinguished position he now held.

The following paper was then read :—

AIR ROUTES OF INDIA.

By LIEUT.-COL. I. A. E. EDWARDS, C.M.G.,

Chief Technical Adviser, Department of Civil Aviation, Air Ministry.

Air routes of India ! It is probable that in the early days of air transport, India, to a greater extent than any other part of our possessions, occupied the attention of the enthusiasts who hoped to see the realisation of their dreams

by the early establishment of air services throughout the more highly civilised parts of the Eastern hemisphere. The reason for this is not far to seek. Generally speaking, the terrain of India is admirably suited for aviation. The climate, except for the short time during the monsoon period, is ideal; especially is this so in regard to night flying. The numerous large business centres of India are widely separated and the existing communications are admittedly poor. In this connection I doubt if it is realised that the mail express from Calcutta to Bombay averages only just over 30 miles per hour throughout its run, while the average throughout all services is only 19 m.p.h.

In addition to the advantages which India offers for the internal establishment of air transport, the fact that she lies on the highway to the still farther East renders her development, aerially, of paramount importance. I will speak of this in detail later on.

Before dealing with India itself, it will perhaps be of interest to look closer at home, and consider for a moment the development which has already taken place in Western Europe, and to see how, as these developments continue, they are likely to play an important part in linking up not only with India but with all the rich territories which lie beyond her realms.

As most of you probably are aware, air transport commenced in 1919, and the slide which I will now show you will indicate the enormously rapid growth which has taken place in the establishment of air routes during the eight years which have elapsed.

But these figures which you see do not tell the whole tale, because in 1919 the majority of the aircraft used were small ones, whereas to-day they are steadily increasing in size. Consequently, while the route mileage is constantly increasing, the ton mileage flying over these routes is increasing with still greater rapidity.

Perhaps if I now show you two further pictures, one illustrating the air routes which were in existence in 1919 and then the air routes which are in existence to-day in Europe, you will get a still better idea of the rapid development which has taken place.

On practically every one of the routes which you see before you regular daily services are being operated, and over some of the routes several services are run daily. It will clearly be seen that there are few places of importance in Europe which to-day cannot be reached by air travel.

Before considering the further routes which will link up the European system of transport with the Far East, let us consider for a moment the justification, if such is required, for the establishment of Imperial air services and the consequent subsidising of the same during their period of infancy. I will now show you a picture which perhaps will illustrate more clearly than anything else could, the value to the British Empire of linking up its various components by means of air services.

This map shows what will happen as soon as these links are established. As you will see, Australia will be brought to the position which Aden now occupies. India will be superimposed over Egypt; South Africa will come to near the present position of Gibraltar, while Canada will lie just off the West Coast of Ireland; in effect, air transport will result in squeezing our Empire together, and clearly, as the speed of air transport increases, this squeezing up effect will be more marked.

Perhaps you will permit me here to draw attention to a fact which probably most of us vaguely realise, yet don't full appreciate, namely, that when we speak of the relative position of one place on this world's surface with regard to another, we talk of distance, but what we really think of is time. For example, I doubt if the average person was asked how far it is from England to India, or from London to Edinburgh, whether he could tell you, but probably the majority could tell you how long it takes to get there. Time is the vital factor, and, as I think you will realise from a study of this picture now on the screen, air transport can effect a greater saving in time than anything else. It is a well-known fact that shipping companies are unable to speed up their ships to any very marked degree without an inordinate increase in cost; the construction of railway lines is in many cases quite out of the question and, consequently, it is clear that the only way in which we can possibly speed up transport to any serious extent is by means of the air.

It might not be out of place here to consider for a moment very briefly and very generally what would be some of the effects of speeding up communications between the outlying portions of the Empire and its heart at home. Obviously the speeding up of transit will, from a business point of view, save vast sums of money in interest on drafts, bills, etc., which at present represent so much money taken out of circulation during the time that they are in transit. The rapid delivery of samples will assist our manufacturers considerably by shortening the time during which it is necessary for them to hold stocks, by freeing the capital represented by those stocks and by allowing them to get a quicker turnover. By the speedy transfer of shipping documents by air, goods can be cleared immediately upon arrival thus avoiding the charges which arise when, as so frequently happens to-day, goods arrive in advance of the documents. From a political point of view there can be little doubt that the co-ordination of Imperial policy must be greatly facilitated by making it possible to hold frequent conferences and to replace in some measure correspondence by personal interview.

Another side of the picture, and a most vitally important one, is that of emigration. This country to-day is admittedly over-populated, whereas practically every part of the Dominions and Colonies is crying out for a larger white population. To-day probably one of the greatest hindrances to emigration is the thought at the back of the mind of the would-be emigrant of the feeling of wide separation which will exist once he establishes himself

in one of the Colonies, and I believe it is largely that feeling which deters a great number of people from embarking on what is more or less an unknown venture. Shorten the time which is involved in this separation and I believe we shall have removed one of the greatest hindrances to an adequate spreading out of the population throughout the Empire.

Brief as this survey has been, I think it will have been sufficient to indicate at any rate some of the enormous benefits which will result from the linking-up of the Empire by air.

Now let me endeavour to show you what are likely to be the main lines of development.

The picture which you see before you shows some routes which are now in existence, others which may be developed as alternatives, and others which will certainly be developed in the not-far-distant future. Working from north to south you will see that there is a line running from London *via* Cologne to Berlin, with an extension to Moscow. This line is in regular operation, and proposals are on foot to extend it further right across Siberia *via* the general line of the Trans-Siberian Railway to Vladivostok, with a branch to Pekin. The next is a line from London-Cologne on to Prague through the Balkan States to Constantinople, the section from Cologne to Prague not being in operation. Joining in with this line is one *via* Paris east to Prague, which is flown daily during the summer months. An alternative route running partly over the same ground will possibly switch off at Belgrade and run down to Athens *via* Salonika, which will then be continued eastwards *via* Rhodes and Cyprus to Haifa, and thence join with the Imperial Airways service now operating from Cairo to Basra, while a branch line may run from Haifa to Egypt. Two alternative lines from Athens may be followed, a northern line *via* Asia Minor to Aleppo, or a southern line to Cairo *via* Crete. Then, coming still further South, a line will probably run from London *via* Paris to Basle and Zurich and on to Milan, thence through Italy and across to Athens. Still another alternative will be for this route instead of going to Athens to run south across the Mediterranean, either *via* Malta to Khoms, Benghazi and on to Egypt, or else from Italy to Benghazi direct, and thence onwards. While further south we have the alternative route: London-Marseilles-Corsica-Naples-Athens, with an alternative from Marseilles *via* Corsica to Malta, where it would join up with the route previously mentioned. Still further south we come to the possibility of a line from Marseilles *via* the Balearic Isles to Algiers, then on to Tunis and along the north African Coast; and, lastly, a line from London *via* the North coast of France around the coast of Portugal to Gibraltar, and then eastwards along the North African Coast, touching at Malta *en route*.

Each of these routes has its advantages and disadvantages; some are longer than others; generally speaking, those through Central Europe traverse bad weather regions, while the Mediterranean traverse good; political difficulties occur on some which are absent in another, and I can confidently state without

fear of contradiction that the choice of the most suitable route is one of extreme perplexity.

From Egypt a route has already been established and is in regular operation from Cairo to Basra *via* Baghdad, and had it not been that certain political difficulties arose with regard to Persia this route would to-day have been in operation as far as Karachi. It is hoped that these difficulties will disappear in the near future. This line is operated by the British Company, Imperial Airways, Ltd., who since the commencement of the service, which is a weekly one in each direction, have flown with the utmost efficiency and regularity which is reflected by the steady increase in traffic which is offered.

A service in extension of the Paris-Constantinople service is contemplated by utilising a wagon-lit to Aleppo and from there an air service would carry on passengers to Baghdad to connect with the British service.

In the event of it being found impossible to come to an amicable settlement with Persia it is probable that the route on to India will run *via* the south shore of the Persian Gulf and thence across to Baluchistan and so to Karachi.

In addition to these routes which leave Europe at some point between Turkey and Egypt it will be seen that there is a further route *via* Moscow to Teheran and thence on to Bushire, which will also feed India

Now consider for a moment what is likely to happen to the East of India. The main route will undoubtedly be from Calcutta, to Rangoon and, from an Imperial standpoint, on to Singapore and *via* the Dutch East Indies to Australia. It is possible that in time a second line will be developed from Calcutta direct to Mandalay and thence, *via* the Shan States, across Cochin China to Hanoi and on to Hongkong. It is even possible that eventually a line may be established from Calcutta following the Brahmaputra and thence over the comparatively speaking short neck which separates it from the Yang-tse-kiang, whence the line would follow the river on to Shanghai.

It is clear that of the two routes to the Far East, namely, that through Siberia and that entering India at Karachi, the latter will be the most important since it will provide communication between England, India, Burma, the Malay Straits and Australia, between Holland and her valuable colonies the Dutch East Indies, between France and Cochin China, and also between England and her large commercial interests in China.

Here I should like to emphasise the vast importance which is likely to attach to quick communication with Australia in days to come. Australia is a land where the potentialities for development are literally enormous. As yet the surface is barely scratched

The development of Australia is marching side by side with the development of aviation which is already playing an important part there, but is undoubtedly destined to become the most potent factor in developing the vital resources of that continent.

Imagine Australia as a second United States, and there is no reason why she should not be, the growth of which has been largely, if not mainly, brought about by air, and then consider the importance which will attach to the Indian route which will connect this hive of industry with the Homeland. I commend to your notice this month's issue of "Air," in which appears an excellent article setting out the developments which are taking place in Australia and the urgent demand for more and more services. Australia to-day has 3,500 miles of air route in regular operation and these are shortly to be increased to 8,000 miles.

Japan is now about to institute regular air transport, and the first line to be put in operation will tap important centres throughout the Islands and will then be extended across to Shanghai. Once a line is established from the West as far as Hanoi and Hongkong, it can only be a short time before it is extended to serve Canton and join up at Shanghai with the Japanese service. It is true that once the line to Vladivostok and Peking from Moscow is opened a shorter route to Northern China and Japan will be provided than *via* the route traversing India, but in spite of this fact it is quite clear that the bulk of the traffic between Europe and the Far East will traverse Indian territory and will not follow the Transiberian route. Calcutta, therefore, as the gateway to India from the Far East, must assume vital importance in the development of air transport.

Now let me leave for a moment the actual routes themselves and consider how traffic is likely to grow over routes in the not-far-distant future. It has already been emphasised that air transport provides the most efficient means of reducing time in transit. The establishment of routes and the operation of air transport is, however, a somewhat costly business, and every mile which can be saved on every route not only effects a saving in time but effects a saving in expense. The man who is going to buy flying naturally wants to get the best value he can for his money, and consequently pure commercial demands will call for the establishment of services over the shortest possible routes. An important consideration so far as India is concerned is that once a line is established from Cairo to South Africa it will immediately bring traffic to India, since, in the first place, there is a large Indian population scattered throughout this African route, and, in addition, large quantities of gold are despatched regularly from South Africa to India. It follows, therefore, that even when a shorter route is established, that from Cairo to Baghdad will still remain and will carry a large volume of traffic.

So far I have referred only to heavier than air routes, but another important factor in air transport is likely to be provided by airships.

This picture which I will now show you indicates the probable airship routes of the near future. Here let me emphasise that the airship will not be a rival of the aeroplane but will work in close co-operation with it. The airship will

fly by long stages. For example, the first stop after England on the route to the Far East is likely to be in Egypt, the next stop at Karachi. The aeroplane at these two points will act as a collecting and distributing service for the airship not only from points off the airship route but also for places along it at which the airship does not stop. Consequently, there is plenty of scope both for the establishment of airship and aeroplane services over the same route; in fact, one will create traffic for the other.

So far I have referred to aeroplane routes without specifying whether these are likely to be operated by aeroplane or by seaplane, but here I will say that I would not commit myself at the present stage to a definite statement one way or another over any untried route, as this must depend on operational experience gained from experimental flights. I contend that the trunk routes which will be followed will be the shortest routes, always assuming that they touch at points at which they are likely to obtain trade and at which supplies can be provided, and that, consequently, the final decision will almost entirely depend on whether the shortest route lies over land or water. In some cases, such as, for example, from Calcutta to Rangoon, it would be possible to establish either an aeroplane service or a seaplane service, and here, at any rate, in the early days, the final choice is likely to depend on the cost of making aerodromes versus the cost of providing seaplanes bases and the meteorological conditions which are likely to be met with when flying over land or when flying over the sea, in this particular case, in the monsoon period. It must be realised that because you have a sea coast it does not necessarily mean that it is desirable to fly along that coast with seaplanes, since in many cases it is quite impossible to find sheltered harbours from which to operate, and which, though not essential for what may be described as spectacular flights, are definitely essential for the operation of regular services.

One consideration which looms out at the present time in the selection of aeroplane routes is the political considerations involved; that is to say, some nations wish to reserve to themselves the whole of the air transport over their own territory. This is perhaps natural in the early stages of air transport, when traffic has to be created, which is, comparatively speaking, a slow business and in consequence of which there is not too much to spare to be divided up between rival companies. This, however, must be only a passing phase. The day will come, and that not far distant, when the volume of traffic over any trunk route will be so great that there will be room for many companies to operate without damaging the interests of each other, and let it be remembered that every additional route created, whether it be a main route or a local one, that is to say every increase in the network of air routes, will automatically create more traffic for the whole as it widens the field of collection and delivery. As soon as this occurs, the location of the trunk routes will be mainly influenced by the distance of the route between any given points, the trade which exists, and the meteorological conditions prevailing on those routes,

and with regard to the last item I confidently believe that the day will come when we shall be able largely to ignore weather and, incidentally, physical features such as mountains, which are so closely associated with bad weather.

To summarise briefly the foregoing, it will be seen that the majority of the traffic for the Far East will be concentrated on Karachi on one side of India and at Calcutta on the other side. Moreover, it will be seen that Calcutta will become, if not the most important air junction in the Eastern Hemisphere, at least only second to the big air junction which must eventually be established either in Syria or in Palestine.

Now, before discussing the actual and probable internal routes in India, it may be worth while considering what an air route consists of and what are its requirements. First of all, terminal and intermediate stations are required, preferably at centres which are likely to produce traffic. At these stations, which should be anything from 200 to 350 miles apart, there will be required landing grounds, hangars at some and not at others, which will depend largely on time tables, workshops and repair plant at any rate at one of the terminals, meteorological and wireless organisations, light houses or beacons to light the route for night flying and to indicate the position of the main aerodromes, and obstruction lights, landing lights and, in the case of an aerodrome which is the first landing place inside the territory, facilities for customs and immigration examination.

In present-day air transport it is desirable that the route should lie over moderately flat country if possible, as the presence of hills or mountains necessitates climbing an aeroplane to an uneconomic height in order to cross these natural obstructions, and good weather conditions should prevail.

For seaplane services, aerodromes are replaced by sheltered water, on the shore of which suitable ground exists for the erection of buildings from which slipways can run into the water. In some cases, slipways can be replaced by cranes. In addition, mooring and embarking stages are required.

All aerodromes should be sited as close to the centres which they are to serve as possible, and should be provided with good communications.

The provision of this organisation sounds a somewhat expensive matter, and, generally speaking, in relation to the number of services which are operated or are likely to be operated over trunk routes in the very near future, undoubtedly these costs are a heavy burden. Nevertheless, it must be borne in mind that, practically speaking, very little more organisation is required to provide the necessary facilities for services which, we will say, operate daily, or even hourly, than is required for services operating only on a weekly basis. The vital necessity, therefore, is the provision of traffic in sufficient volume to allow for numerous services to be operated when the overhead costs involved in ground organisation and in operation can be distributed over a large number of services instead of only a limited number. There is nothing mysterious in the operation of air transport. It follows largely the principles which apply

to every other form of transport, namely, that your vehicles, whatever they are, must be used to the maximum extent possible.

Here I might remark, in passing, that at the end of 1920 an estimate was got out by the Government of India for the provision of the ground organisation which it was considered would be necessary to operate services from Bombay to Calcutta *via* Allahabad and on to Rangoon. In the light of experience which we have gained to-day, I think this estimate was considerably below the mark, but the figure quoted was approximately 26½ lakhs, and the route mileage was just under 2,000 miles. Even assuming that this figure was underestimated by more than 50 per cent., and we put the cost at 60 lakhs, it will be seen that the cost of establishing an air route of this nature would work out at 3,000 rupees per mile. I understand from enquiries which I have made that the average cost of constructing a single line of railway in India and providing it with all the necessary ancillary services amounts to approximately 2 lakhs per mile.

I put this figure forward with all diffidence, and stand open to correction, as I have been unable to verify it; but, assuming that it is correct, the difference in cost is literally astounding; it means that 70 miles of airway can be established at the same cost as one mile of railway. It will naturally be argued that a railway line once established can carry a vast volume of traffic which an air line would never carry, such as heavy goods, raw produce, etc. That is undeniable. Nevertheless, once a multitude of air services are operating, and as we get bigger and bigger aircraft, there is not a shadow of doubt that a vast volume of goods traffic will take to the air. Already in Europe, where there exists the most perfect system of ground transport, goods of all sorts and kinds, ranging from ladies' frocks to samples of machinery, are frequently to be found amongst the varied assortment of articles which are daily despatched by air. In 1926 the total weight of cargo carried to and from the Continent in British aircraft amounted to 679 tons.

As one class of freight which has an interest for India is frequently carried on the Continental routes it may be of interest to mention it specifically here, namely, the carriage of gold and bullion. In 1926, out of a total of eighty-eight million pounds worth of gold and silver imported and exported from Great Britain, approximately eight million pounds' worth was carried by air. The reason for this is not far to seek, namely, that the insurance rates for freight by air are considerably lower than by any other means of transport, on account of the reduced handling involved, the smaller chances of pilferage and the impossibility of theft while in actual transit. This form of freight will closely affect India, which is a very big importer of bullion, and consequently it may be of interest to note that a considerable move is taking place in South Africa for the establishment of a through route from South Africa to Egypt, where it would connect with the Egypt to India service, this being mainly sponsored by the gold interests there. In addition to the reduced insurance rates for

transport of gold by air there is also the additional considerable advantage of the saving of interest during time of transit.

Now let me deal with the internal routes of India. The first is that from Karachi *via* Delhi and Allahabad to Calcutta and from Karachi to Bombay to connect with the Egyptian service. The next in importance of the true internal services is that from Bombay to Calcutta. Especially is this the case since it is possible that in certain weather conditions the airships will touch at Bombay instead of Karachi, but in any case there exists to-day a large volume of traffic both in the form of passengers, mails and goods between these two places. Then an important service will doubtless run from Calcutta *via* Benares, Cawnpore, Allahabad, Lahore to Rawalpindi. To-day there is a vast volume of traffic on this route. As an example of this I might quote that in 1921, if my memory serves me correctly, a train left Calcutta for this route every night about 8 p.m., which was called a "special parcels express." This train consisted of twelve wagons each capable of carrying ten tons, making a total of 120 tons which nightly left Calcutta. I was given to understand that this train always went out fully loaded, and that on the majority of occasions there was a considerable overflow which was put on to the ordinary passenger train. Of this 120 tons it is obvious that a large quantity would be suitable for air transport, and remember that only a very small percentage of this load would be sufficient to fill completely one aircraft. Then from Calcutta there will be a further route following the coast, *via* Visagapatam down to Madras and on to Colombo, at which point it will probably tap in with the airship service. There will be a similar connecting service from Bombay across to Madras and on to Colombo. Incidentally, there will probably be two routes from Bombay to Calcutta, one *via* Nagpur and Jharsaguda and the other *via* Jubbulpore and Allahabad. The former route is approximately 200 miles shorter than the one which follows a more northerly course, and the saving in time which would be involved on this route will make for considerable simplification in arranging for connections on the extension of the route to Rangoon. It is inevitable that, at any rate, one of the Bombay-Calcutta routes and a section of the route from Karachi to Calcutta will be operated by night.

Even as early as 1919 detailed schemes for the operation of a service from Bombay to Calcutta and on to Rangoon were submitted to the Government of India, and of these the former was to be operated by night. India offers the most ideal country for night flying; in fact, in the hot weather season it is undoubtedly preferable to day flying.

Then we come to possibly the most important service of all, also based on Calcutta, namely, Calcutta to Rangoon. This is likely to be the first service to be put into operation, as the benefits which it will confer on these two places are self-evident. All the other points which have been referred to in India are already connected by train services, whereas Calcutta-Rangoon is dependent

on ships only. Flying day and night passengers, mails, etc., leaving Bombay at 6 p.m., should be able to arrive at Rangoon on the following day by 6 p.m., as compared with a lapsed time by ground transport of approximately five days and nights, assuming that a connection is established at Calcutta.

I will now ask you to look for a moment at this picture which shows in tabular form the distances and the saving of time which will be effected as soon as the air routes to which I have referred are in operation.

In this paper I have made no effort to deal with the economics of air transport, but have confined myself entirely to air routes, and in so doing I hope I have impressed upon you the tremendously important part which India is destined to play in the future of air transport. Remember that already in Europe vast strides have been made, similarly in Australia wonderfully efficient services are operating. The Dutch East Indies and Japan will soon have routes in regular operation, while it is probable that a British service will be flying in the Malay States within a short time. India is the connecting link to all these services, and consequently cannot remain indifferent without creating an absolute barrier to the development which is taking place on either side of her. It cannot be long before London is only six days from Karachi, and she has little time to spare if she is to be ready when that happens. The link was forged when Sir Samuel and Lady Maude Hoare flew over from England to Delhi and back to Cairo at the end of 1926 and during the early part of last year.

Now what effect is the establishment of these services in India likely to produce? The external services must inevitably bring increased trade as the direct result of speeding up the foreign mails. The writer of a letter in England to-day can normally expect an answer from India in six to seven weeks, as against two weeks which will be possible by air; contracts will in consequence be negotiated in a fraction of the time which is now required, which is all to the advantage of commerce. Reference has already been made to the saving which will be effected by the rapid transfer of drafts, bills, bullion, shipping documents, etc., while the increase in trade which will certainly follow as soon as it is possible for business men at home who have interests in India to pay frequent personal visits there and *vice-versa* is obvious. Under present conditions these visits are, comparatively speaking, of rare occurrence, not on account of the cost, but because of the time involved in making such journeys. Reduce that time by two-thirds and the conditions immediately become entirely different.

As the external services will stimulate the external trade of India, so will the internal services stimulate the internal trade. Take, for example, the man in Calcutta who wants to put through some business in Bombay which will necessitate spending a day or part of a day there. Under present conditions he must be away from Calcutta for the greater part of four working days in order to spend less than half a day in Bombay, and if he wants to spend a day there he must be away five working days. People are apt to say, "what is

it going to cost?" Even if it costs three or four times as much as a first-class railway fare, the traveller will still be the saver in the long run when the value of his wasted time is taken into consideration. Whereas as soon as a night air mail service is established he will be away for the one working day only. I speak from bitter experience, having on two occasions made the journey for the pleasure of half-an-hour's discussion of a matter on which it has been impossible to reach agreement by the exchange of letters. Dozens of journeys are never made because the time cannot be spared for them, and dozens of contracts never mature in consequence.

Turning to lighter things, imagine how cheerfully the hot weather could be faced if it were possible to put in week-ends, or even an odd day's golf, say, in Kashmir, a mere hour's flight from Rawalpindi or Jhelum, which is not only within the realms of possibility but of probability. Then, the comfort: many of us have realised the discomfort of train travel in the hot weather: the dust of the Sind Desert. An air journey is clean and cool. In fact a journey by air will act as a tonic as good as any which a visit to a Hill station would provide.

The establishment of a daily service between Calcutta and Rangoon which will be accomplished in about ten hours must clearly result in expanding the trade which now exists between these two important business centres. The boat sails twice weekly, and is scheduled to take fifty-two hours over the journey. The comparison between the two gives such an enormous advantage to the aeroplane that it cannot fail to attract a considerable portion of the existing traffic, and will doubtless create a considerable volume which is at present non-existent.

A question which naturally arises is, how will the monsoon affect services? I am of opinion that except under very exceptional circumstances it will be possible to maintain daily services throughout India over any scheduled route, but that the time tables will suffer from loss of regularity. It is admitted that there is insufficient experience to-day on which to base definite statements. Now consider for a moment what has been done in India and what is being done.

In 1919 a temporary service was operated between Karachi and Bombay by Royal Air Force personnel and machinery. To the best of my recollection the Director General of Posts and Telegraphs initiated this scheme. It was primarily a postal service. An experimental service does not offer sufficient opportunity adequately to advertise for mails or to show the advantages which an air service can offer. Moreover, there is in no case a large exchange of mail between these places as compared with other terminals in India. The cost involved was prohibitive, as a complete squadron of the Royal Air Force was detailed to this work, which could have been comfortably done by three machines and a few mechanics. The result was a lamentable failure and I believe did more to hinder the development of air transport in India than anything else. I wish to emphasize, however, that this failure was in no

way attributable to the Director General of Posts and Telegraphs, who was the best friend which Civil Aviation has ever had in India. This was followed by the arrival in India of an expedition consisting of three Handley Page machines and about twenty-five British personnel, sent out by Messrs. Handley Page Transport, Limited, the object of which was to obtain air mail contracts between Bombay and Calcutta and Calcutta and Rangoon. The Government of India were, however, afraid of air transport and would not play, and after two years of strenuous work the company was closed down. It achieved something, however; it succeeded in the face of great opposition in getting the import duty on aircraft reduced from $7\frac{1}{2}\%$ *ad valorem* to $2\frac{1}{2}\%$, and got the Calcutta aerodrome made at Dum Dum, while it educated a considerable portion of the Indian public to the latest possibilities in aviation as the result of giving joy flights and distributing vast masses of propaganda. Incidentally, it also made the personnel of the expedition sadder and wiser men; I speak with knowledge, as I was one of them.

In the meantime the British Government had presented the Indian Government with a large number of surplus war-time aeroplanes, some of which were given to certain ruling princes, while others found their way into the hands of private owners who, from time to time, made various attempts to start aviation businesses, without, however, meeting with any real success.

The first real step forward was made the year before last when the Government of India issued a memorandum on its policy and later appointed a Director of Civil Aviation. Prior to this, however, owing to the desire of the Home Government to operate an experimental airship service between England and India, and also because the British Government had entered into an agreement with the Imperial Airways, Ltd., for the operation of a regular aeroplane service between Cairo and Karachi, the construction of a combined airship and heavier-than-air port was put in hand at Karachi, and this is now nearing completion. This will eventually be equipped with a mooring tower, an airship hangar, gas plant, aeroplane hangar, offices, quarters and wireless and meteorological installations. In addition, civil aerodromes have been provided at Uterai, Jodhpur, Nazirabad, Agra, Cawnpore, Allahabad, Patna, Calcutta on the route Karachi-Calcutta. In addition, there is an aerodrome at Akyab, on the Rangoon route, while Bombay has had an aerodrome on and off. Recently an Aero Club has been formed in India, which will organise Light Aeroplane Clubs, air meetings and so forth; already four clubs are in course of formation, three of which will be at the following places, Karachi, Delhi and Calcutta.

An air development, though not air transport, which has recently obtained a footing in India is the very important one of air survey. The Air Survey Company was first formed to take up a contract for the survey by air of a large area in the Irrawaddy Delta some four years ago, the success of which was so immediately apparent that further contracts were obtained farther

East, at the conclusion of which the company moved Westwards again, and, after carrying out a survey during last spring near Chittagong, is now busily employed in Bengal, in the Malda District, on making an air survey of from sixteen to eighteen hundred square miles in connection with land settlement. The speed of air survey, combined with its accuracy and cheapness when conditions are favourable, as happens in this instance, are likely to produce a continually growing demand.

Before concluding by showing you a series of pictures illustrating some of the various types of aircraft which are operating in Europe and are likely to be seen in India in the not-far-distant future, I would emphasise again the fact that India offers the most wonderful opportunities for the development of air transport, and, moreover, it is ripe for development in that a large portion of the population of India is wealthy, and, in addition, the Indian is ready and anxious to fly; consequently the somewhat slow process of education which is necessary amongst European peoples is entirely unnecessary with the Indian.

The majority of the routes to which I have referred are of the future. That, however, from Karachi to Calcutta is already partially established, while that between Calcutta and Rangoon is under contemplation. Reconnaissances have already been carried out, and various estimates of the cost of preparation are under consideration.

To recapitulate, already large sections of the route between the far corners of Australia and England are either actually operating or are about to be operated. To-day it is possible to fly from London to Constantinople. In the near future it is hoped that it will be possible to get from London to Cairo. A route is already in existence from Cairo as far as Basrah, which it is hoped will be extended on to Karachi and Delhi.

Discussions are at present taking place with regard to the possible establishment of a service in the Malay Straits from Penang to Singapore, with a possible weekly extension to Calcutta *via* Rangoon, and a service has already been agreed upon for the establishment of routes through the Dutch East Indies which next year will probably connect Singapore with Surabaya. In Australia a route follows the West Coast from Wyndham down to Perth, and the East Coast will very soon have a route from Port Darwin to Brisbane, with extensions on to Sydney. It will thus be seen that within the next year or so considerable links in this great Imperial route will have been established, and it will only remain to connect up the remainder to have a through route all the way.

In air transport, as in the majority of other things, the difficulty is to make the first start, but it can confidently be anticipated that once services are operating over the main stages the connecting up of the remaining links will only be a matter of a short space of time.

I will now show you some pictures of types of aircraft which it is hoped will be flying in India in the comparatively near future.

DISCUSSION.

THE CHAIRMAN said the paper was not without provocative points, and he would like to ask Col. Edwards to amend it in one particular. He referred to his statement that the first link in the chain of Imperial air communications was forged by Sir Samuel and Lady Maud Hoare when they flew from Cairo to Karachi. He ought to have said that it was forged and immediately broken, because his reference to the matter in the lecture gave the impression that that link still remained as a complete entity, whereas in fact it was immediately broken owing to political difficulties.

He heartily agreed with the lecturer's remark on the future of the flying boat. He looked to the flying boat, so far as heavier than aircraft was concerned, as being one of the mainstays of our lines of communication in the future.

One point that emerged from the paper was the great difficulty that was being experienced, and surely would be experienced, in running British routes over foreign territories, because we were dependent upon the good will of those administering such territories as to whether we might or might not run a route there. This pointed to the desirability of trying to run British routes by means of flying boats, utilising, where possible, the bases already used by our marine services.

There were many who did not believe in air transport at all, and were always telling people at large about their disbelief. Recently someone had drawn attention to an extract from *The Times* of 1842, wherein were given details of the railway services in England in 1841. In that year the distance covered by all the railway services in Great Britain was 3,562,338 miles. During that period it was stated *only 56 passengers were seriously injured, and of these 22 were killed*. When it was remembered that railways had been established for twenty years when those records were taken, it would be appreciated that the record of air transport was not at all an unsatisfactory one, when taking into consideration the fact that the number of miles covered by Imperial Airways Services during 1927 was 651,465. During the year, as was the case in the two previous years, *not a single casualty occurred* in connection with the running of those services.

Col. Edwards had laid a good deal of stress upon the carrying of passengers, but he (the speaker) wondered whether it would not be more profitable in every way to carry first-class mail and goods, provided always, of course, that we had a sympathetic Postmaster-General who would see that the necessary freight was made available.

MAJOR H. JULLEROT (of Messrs. Vickers, Ltd.) said he could not entirely agree with the lecturer that the heavier-than-air machine should be purely subsidiary to the airship, although he believed that the airship, with its enormous load capacity, would always be superior to the aeroplane and to the seaplane for goods, as well as for passenger-carrying in certain conditions. The airship could not weather the same storms as a heavier-than-air machine. He hoped to see come into existence a machine which might almost equal the capacity of an airship, namely, a huge seaplane. He felt that the ultimate future of aviation lay in that direction. At present the largest heavier-than-air machine weighed some fifty tons, and this, he thought, was about the limit of the size of the land plane; but he hoped it would be possible to build a seaplane of one, two, or even three thousand tons, capable of carrying a large load of people, and of being converted, in case of need, into large bombing planes. Airships were useless for the latter purpose, as had been shown during the war by the fate of the Zeppelins. The future lay with

the large all-metal seaplane, and for these it would be necessary to build round the harbour adequate protection, in order to give a fairway for taking off or landing.

COLONEL C. H. D. RYDER, C.B., C.I.E., D.S.O., late R.E. (formerly Surveyor-General of India), alluded to the great value of aircraft for the purpose of surveying the surface of countries. He had been connected with surveys in India for nearly forty years, and as an old surveyor he had originally been rather sceptical as to the possibilities of aircraft for survey work; but after some experience he had no doubt whatever that in the future surveys, in certain circumstances and of a certain nature, would always be carried out by means of air photographs. Anyone who had been in India would know how very unpopular the settlement surveyor was with the landowners and with the villagers. Surveyors came down upon them rather like a swarm of locusts, and were not always above taking bribes, and making suitable and useful mistakes in the boundaries and the size of holdings; and all that was swept away by the taking of air photographs, which had become the ideal method of carrying out inch surveys. The photographs were perfectly accurate, as nowadays there was no difficulty in flying perfectly straight and in flying on an even keel; and the maps showed more detail than a ground survey would do, and were cheaper. Air photography was not suitable for every type of country, but for countries like India and Egypt, where a good deal of the country was level, it was most useful.

COL. H. L. CROSTHWAITE, C.I.E., late R.E. (formerly Superintendent, Survey of India) said Colonel Ryder had said practically all there was to be said on the subject of air survey. He might add, however, that in very jungly country the air photographs also formed a means of classification of forests, which was most important from a forestry point of view. One could now carry on the ground control by means of wireless time signals, so that one could fix one's position for small-scale maps, which would be used in the development of new countries, by means of astronomical latitudes, and astronomical longitudes and time signals which were quite independent of anything else. Thus the expense of, and the time involved in, forest clearing for purposes of triangulation or traversing was saved. Added to all this, maps could be produced in a very much shorter period by the air method than by normal survey. This was an element of considerable importance where the development of new countries was concerned. If correctly applied, and the area were large enough, air survey had many advantages over ordinary ground work.

SIR ROBERT MCLEAN (of Messrs. Vickers, Ltd.) said he also had found the lecture somewhat provocative. He had been in India for twenty-two years as a railway man, and was now responsible for the conduct of a large aircraft manufacturing company, so he hoped he spoke with impartiality, but he thought it was a mistake to make any comparison in terms of money between the cost of building a railway and the cost of laying down an airway. The cost given by the lecturer was 2 lakhs of rupees per mile for a railway. That was about twice as much as a light branch line cost at present, and for that sum of one lakh a mile one got sufficient equipment to carry probably 5,000 tons a day in each direction. An airway might be put down for 3,000 rupees a mile, but a vast number of aeroplanes would be required to carry 5,000 tons a day in each direction. He therefore doubted if the interests of civil aviation were served by comparisons of that nature. As one who was interested in transport, he believed that there were enormous openings for civil aviation, and

that the functions of air and rail systems did not conflict in any way, but should be regarded as complementary to each other.

MR. GEORGE BLACK agreed with the lecturer that the time factor was of great importance and this had impressed him personally because it seemed probable that he might soon be able to do the journey from London to Borneo in a few days, whereas at present it took six weeks.

The organisation of the future trunk air lines across India might, he thought, be safely left to the authorities and to Imperial Airways, but internal passenger and mail services in India might be left to private enterprise. In view, however, of the lack of local enthusiasm, it would be necessary to do a good deal of educational work, and to exercise caution in the initial stages, so as to avoid bringing the movement into disrepute. Expensive lessons had been learned in Europe and America on the financial side of such ventures, and it would be a pity if full advantage were not taken by India of these lessons. It was a pathetic sight to see a large 14-passenger liner carrying only two or three people. It seemed illogical to use a 14-passenger machine, costing perhaps £25,000, rather than three of the new D.H. Canberra machines at a total cost of £15,000, which would collectively carry the same paying load. This would effect economy in running costs, besides "splitting the risk," which was important both financially and from the point of view of disturbing public opinion in the event of a crash.

He thought that Allahabad would eventually become the Croydon of India as far as internal services were concerned, being the natural centre for all Indian air routes, and having a natural aerodrome of dimensions capable of dealing with any number of land machines, while its situation at the confluence of the Jumna and the Ganges rendered it equally favourable for flying-boat services. Sir Alan Cobham, Messrs. Leete and Stack and others had utilised the advantages offered by Allahabad.

He was glad to learn from the lecturer that four light aeroplanes clubs were in course of formation in India, though it was disappointing to read in the *Pioneer* of the lack of local public enthusiasm.

There appeared to be a real danger of the Indian flying services falling into the hands of foreign corporations, and it therefore behoved the authorities and those commercially interested to be alive to this possibility and its disastrous consequences to the British aircraft industry.

SIR LOUIS DANE, G.C.I.E., C.S.I. (late Lieutenant-Governor of the Punjab) said the lecturer had referred to the fact that the main air route to India had been cut in the middle at the Persian Gulf owing to certain political and commercial trouble with the Persian Government, and the possible dangers of Wahabi disturbances on the south coast. It was to be hoped that both those causes might only be temporary, but Britain did possess a position at Basidu on Kishm island in the Persian Gulf which, so far as his memory served him, was quite suitable for either air boats or aeroplanes. This might serve as a temporary base at any rate.

It should be remembered that the Persian Government were not altogether unreasonable in suggesting that any aeroplane route passing through Persia should be of some use to Persian territory. A line going from Basra to Bushire and on to Bunder Abbas was no use to Persia, but an aeroplane service from Basra to Ahwaz, the Anglo Persian oilfield, Behbahan, Shiraz, Kerman, and to the railhead at Duzdap on the Baluch boundary would be of great importance both to the Persian Government and to the British Empire. This route was about 500

miles shorter to Northern India and Delhi than the route by Karachi, and passed through a better country for land machines than the other, and the temperature was much more equable than the horrible climate of the Persian Gulf.

It was practicable for motors for most of the distance of about 750 miles over which a railway did not exist, and the short distance, over which there might be difficulties, had been shown to be practicable for a railway or motor road. If this route for aeroplanes were combined with the Gulf route for airships and seaplanes the Persian Government might be more willing to permit the use of their territory for air routes to the East.

COLONEL N. T. BELAIEW, C.B., asked how the costs would compare for, say, 1,000 miles of route for aeroplane and for air boats respectively.

MR. GEORGE PILCHER, M.P., said he was afraid he was one of the sceptics mentioned by the Chairman. He thought there was very little real comparison between the railway position in England in 1842 and the air position in India in 1928. It was a mystery to him how people in Europe should regard India as a suitable place for the most expensive form of transport in the world, India being one of the poorest countries in the world. The highest average annual income ever attributed to her population was £4 a head, and in Lord Curzon's time it was put at about £2 whereas in England the average taxation was £18 a year.

With regard to comfort, certainly the railway journey from Calcutta to Bombay or to Peshawur was not uncomfortable, but he would not like to spend many hours in the inside of a 20-seater aeroplane. How Lady Maude and Sir Samuel Hoare had borne their journey he did not know. It seemed to him that Lady Maude must be one of the most wonderful women ever born, and he was glad she had got a very high decoration for all she had gone through.

THE CHAIRMAN said that in drawing attention to the extract from *The Times* of 1842 he ought to have mentioned the fact that shortly before that, monster petitions signed by thousands, if not hundreds of thousands of people, were being presented to Parliament praying that Parliament would definitely limit the speed of the railways to eight miles an hour, because anything more than that would be dangerous. He thought, therefore, that in considering the new form of transport we could benefit by looking back and seeing how people had fallen into certain traps in the past, and by trying not to fall into those traps ourselves.

COLONEL EDWARDS, in reply, agreed with the Chairman that he ought to have mentioned that the link forged by Sir Samuel and Lady Maude Hoare was broken. He also agreed with Major Juillerot that the aeroplane was not merely subsidiary to the airship. He had intended to give the impression that the aeroplane was complementary to the airship, and the airship complementary to the aeroplane, and that one would support the other. As regards the metalling or cementing of fairways, personally he believed that the day would come when concrete fairways would be necessary. The stage had already been reached when it was almost impossible to preserve any aerodrome where heavily laden aeroplanes were used. The machines tore up the surface so much that in a short space of time it became practically unusable. It was becoming necessary to use wheels instead of tail-skids in order to protect the aerodrome surface.

As regards the size of machines, he also agreed that very big machines would come into use, but he did not pretend to be a sufficient prophet to say whether it would become impossible to use aeroplanes of a much larger size than were made at present, or whether it would be necessary to use seaplanes.

With regard to Sir Robert McLean's remarks, he had stated in his paper that he was uncertain as to what the actual cost of laying a railway was, and he wished to thank Sir Robert for the figures he had given. He fully agreed that railways were complementary to aircraft; in fact, there was no doubt that every form of transport must be complementary to all others. He stood corrected with regard to the comparison of the cost of establishing an India railway and an air service, but he had been speaking not so much in reference to Indian as to Colonial development generally. For instance, air routes were being established throughout Australia. It was economically impossible to put down railways everywhere in new country, and the air services made habitable parts of the country which were not formerly habitable. What had actually happened as a result of the establishment of those services in Australia was that men were taking their wives and families to live with them, whereas formerly they were living as bachelors. It was a well-known fact that one could not colonise a place if one could only take the men there. It was now quite easy to get doctors there, whereas formerly it took anything up to three weeks. It was then impossible for women to go unless they were prepared to take enormous risks, while now the case was quite different. Every month records were received of stretcher cases being brought down to hospitals and operated on, or of doctors taken up to treat people. Many people talked about the dangers of air transport, but there was not a shadow of doubt that the number of people who had been killed by air transport was literally nothing compared with the number of people whose lives had been saved by its agency, and that in Australia alone, leaving out other places.

Sir Louis Dane had referred to the alternative route across Central Persia. That route had been studied, and, in fact, many alternative routes through the interior of Persia had been studied. The main difficulty was the difficulty of keeping up supplies. It must be remembered that an aeroplane such as that which had been used on the Indian route or on the partial Indian route consumed, on the average, about 70 to 75 gallons of petrol an hour. The distance across the interior to India was roughly 1,500 miles, and if one had a machine going once a week in each direction it took a colossal quantity of fuel, and all that quantity of fuel had to be transported to difficult localities. In addition to that, it was necessary to provide aircraft spares, engine spares, and all other spares, and keep them distributed along the route, and where means of communication were very scarce it was very difficult to keep those services going. From a money standpoint it was better to operate along the coast, because of the ease of getting spares or stores there. As regards the islands in the Persian Gulf, which had been mentioned, those, also, had been considered, and many other possible alternatives, by zigzagging across various parts from south to north, or *vice versa*, and using the islands, but as far as could be seen at present it meant either changing the type of aircraft, or else putting up so much extra fuel, that the load was cut down to too great an extent.

As to the comparative cost of an aeroplane and a seaplane service, he was afraid it was very difficult to answer such a question offhand, without knowing specifically the route on which it was desired to operate. So many conditions came in that it was impossible to lay down a hard and fast rule as to what any aircraft service was going to cost, because it depended on the length of the stages very largely, on the frequency of the service, and on various other costs, such as import duty on petrol, machine spares, and so on. To-day there were aeroplanes in existence which would, with a reasonable load, pay for their flying costs and show a profit. If that could be done it stood to reason that if one could make a clear profit on the pure flying costs, it was only a matter of putting on enough planes to pay for the overhead

charges. For air transport to pay, it was necessary to have, as in every other form of transport, an intensive operation to cover the overheads. It would be impossible, for example, to run a railway service on one train a day, or to run the L.G.O.C. 'bus service with one 'bus on each of the services. There was no mystery about it. Air transport would come down to a reasonable figure as soon as it was sufficiently patronised. Although the cost of an air voyage to Paris or Berlin was higher than by rail, yet it had to be remembered that a good deal of money was saved in portrages by the air service.

He disagreed with Mr. Black when he said he believed that Allahabad would be the great centre of air transport in India. He himself believed that the actual centre of air transport in India would be Calcutta, though it was only a matter of opinion, the air services being as yet undeveloped.

Mr. Black favoured the use of three relatively small single-engined aircraft in place of one three-engined. This did not seem sound, as, though it was true that, with one machine you were putting all your eggs in one basket, that basket was very much more reliable than its single-engined brother. Moreover, the cost of operating one large machine was considerably less than the cost of operating three smaller ones which in the aggregate carried a similar load.

It must not be forgotten that, though a machine might go out half empty to-day, it might come back full to-morrow. With regular scheduled services, it was necessary to provide the transport facilities advertised, even if the traffic on a few occasions was lacking; otherwise, a complete disorganisation of services would occur, and the travelling public would not be able to rely upon them.

As regards Mr. Pilcher's remarks concerning the poverty of India, this, undoubtedly, was true when averaged throughout the masses, but it was undeniable that there was a very large wealthy Indian population who were only too ready and willing to fly when given the opportunity. As regards comfort, his own opinion was that the aircraft far surpassed the Indian train, especially when it was remembered that the aircraft travelled in cool clear atmosphere while the train crawled through the heat and dust. Noise was being rapidly reduced, and the general consensus of opinion of passengers who had flown in the "Hercules," the type of machine which would be used in India, was that it was not more noisy than a railway train. In the latest type of flying boat conversation could be carried on in normal tones without in any way stressing the voice.

He would not venture further upon the economics of air transport, as it was impossible to deal adequately with so complicated a subject even in a paper entirely devoted to it, still less in reply to a discussion on another paper.

On the motion of the Chairman, a hearty vote of thanks was accorded to Colonel Edwards for his paper.

OBITUARY.

DR. JANE BUCHANAN HENDERSON RUTHVEN, M.D., L.R.C.P.—South African women have suffered a great loss by the death on March 28th at Johannesburg of Dr. Jane Ruthven, who took a leading part in almost every woman's organisation in that city and interested herself largely in aspects of civic affairs especially affecting women. Dr. Ruthven, who received her medical training at the Royal Free Hospital, London, was Vice-President of the Women's Civic Society of Johannesburg, a member of the Society for Mental Hygiene, of the District Nursing Association, and of the South African Society for the Advancement of Science. She had been a Life Fellow of the Royal Society of Arts since 1909. .

NOTES ON BOOKS.

OLD MASTERS AND MODERN ART. By Sir Charles Holmes. London: Messrs. George Bell & Sons., Ltd. Three vols: 25s. each.

There is throughout the survey of painting, recently completed by the Director of the National Gallery, a convincing strain of integrity and moderation. The style is agreeably prosaic, persuasive and unaffected, and the judgments always seem at least to be those of "all sensible critics," though there are a number, especially towards the end, with which one may disagree. The illustrations are good and the book is well printed.

In his introduction Sir Charles Holmes opens with a discussion of the conditions in a picture which go to making artistic value. This approach to the aesthetic problem is interesting; more useful, of course, to those who look at pictures than to those who try to paint them. Artistic value is a compound of vitality, infinity, unity and repose. All these depend on good design, and good design depends on genius—so the analysis is not to be taken as an aid to painting masterpieces.

At the end of volume three Sir Charles strikes a very shrewd blow for genius, not genius as a quality of the intellect but genius as an emanation from, an expression of personality. The fact is that personality contributes to painting and the other arts an essential element, which, in the case of painting, may be called vision. In other branches of life we realise how much personality counts. We should not ignore that it is out of the contact of personality with the visible world, in its unabashed naturalness, that the art of painting arises. The selective processes of art are infinite. Sir Charles urges English aspirants to bear this in mind; we seem to know too much about history and archaeology, too little about our own potentialities. So many moderns are afraid to create because afraid of breaches of taste, while some, who have the temperament of innovators, have unfortunately no ideas to exploit.

In the epilogue to volume one Sir Charles gives an outline of what he considers the reasonable attitude to take towards realism. The realism of the great Dutch painters showed that this quality could enhance the charm of a work of art, while much modern academic work conclusively proves that skill in reproducing the material surface of things is not a necessary element of a masterpiece. And how difficult, after all, it would be to indicate a single criterion of realism, or to name the percentage of realism in the naturalistic but dissimilar work of, say, De Hooch, Zurbaran and Sir William Orpen. The writer does justice to impressionism, and his attitude towards El Greco is the best assurance that left-wing critics could have that his aesthetic health is good.

Sir Charles describes how the technical and psychological histories of art are bound up with the history of the social life of nations, with questions of climate, class distinctions, architectural vogue and general amenities. And if art is to be our guide to life, as in important respects it can be, then our already severely tested faith in progress will be further shaken. Accumulated knowledge may accrue to the race, and not always to its benefit, but it remains skin deep with the majority of individuals. We might have more Leonardos than we do, but not greater ones; Leonardos up to date, but not more significant ones.

Sir Charles has a full, and most interesting chapter on Japanese art, of which, as he deplores, there is no representative collection yet in Trafalgar Square. He comments on the influence on French painting of the Oriental works of art which found their way to Paris in the eighteen sixties and seventies. Speaking of Hokusai, he says that, as with Brueghel, the grotesque was only one facet of his genius;

"on the other hand he was one of the greatest designers of landscape whom the world has produced." There has still to be written a book giving the best grotesque art its due. The present writer has naturally only praise for Daumier, "who made a considerable reputation and a bare living out of political satire," and he points out that Goya, in his fantastic pictures, did not sacrifice art to effect. What is perhaps not commonly recognised is that the impulse to caricature is a more purely aesthetic prompting, than the impulse to reproduce with more or less fidelity the face of nature or of man. Even though successful, caricature inevitably plays on other emotions besides the aesthetic one—assuming this can be isolated by a sort of imaginative compromise; there is no question of its appeal being made to our too literal associations. There are valuable qualities in common between, for instance, Rembrandt's "Woman Taken in Adultery" and some of Daumier's more sombre and remarkable paintings.

If the National Gallery is deficient in Oriental works it is fortunate enough to possess pictures by Rubens almost certainly not touched by his pupils. As Sir Charles says, the essential features of his style can be studied in that amazingly beautiful and intricate panel "The Apotheosis of William the Silent," a singularly rhythmical composition, given repose by the gracefulness of its curves, and vitality by the suggested action of the figures represented, while the colours, which shade subtly into one another, are the explanation of its perfect unity.

The present day—though the air is full of recriminations, accusations of plagiarism or too obvious derivativeness and so forth—will not be neglected by posterity. There are painters in England as well as in France who have originality and force. Of Sickert Sir Charles Holmes speaks with perhaps insufficient emphasis, for this is an artist whose technical graces are alive with inspiration. Duncan Grant, "the most representative and genuine talent among the immediate followers of the French" is also something more. In almost any exhibition of contemporary work his pictures stand out for their solid qualities, what might in fact be called their unity and their repose. Sickert has more vitality and rhythm.

Sir Charles' optimism must not be regarded as what it certainly is not, mere official pretence. Science has taken from us the support once afforded us precisely by our limitations; see what Paolo Ucello could do with limited knowledge and materials. But we have gained as much as we have lost. One very serious difficulty undoubtedly confronts the next generation, however. The legitimate and in many ways fortunate demand for applied art makes things harder for art that is not intended to be applied. Courage as well as genius is needed for the creation of a masterpiece. P.B.

HISTORY OF SCIENCE TEACHING IN ENGLAND. By D. M. Turner. London : Chapman and Hall, Ltd. 7s. 6d. net.

The title page introduces the author as "Head of Science Department, Wycombe Abbey School"; and he commences his preface by telling us that "the aim of this little volume is to indicate in outline the growth of the scientific spirit in England." We now turn to the first chapter, which is headed "Dawn of the Scientific Spirit in England," where we find mention of the migration to Oxford of students from Paris, and here begins the definitely known science teaching in England. After Roger Bacon (pp. 5-6), we have light touches on Copernicus, Kepler and Galileo; these leading back to England through the writings of Francis Bacon, also Gilbert, whose *De Magnete*, published in 1600, marks the well-defined experimental period. Seventeenth century influence is introduced by

a concise but lucid account of the writings of Descartes (pp. 12-18), whose thinking seems to have been instrumental in setting many to experimental work in England. The cosmic or physical system of Descartes is emphasised by Mr. Turner, not for its intrinsic importance, but to show the historical origin of Newton's *Principia*, which arose indirectly from Newton's endeavour to see beyond those speculative hypotheses and vague parallels which then formed the staple of "scientific" writings. On p. 17 the author summarises the matter of the four preceding pages by telling us that "the physical system of Descartes, threatened by that of Galileo, was finally overthrown by Newton."

The study of this portion of the book under notice makes us think of that ancient doctrine that truth emerges more readily from error than from chaos; a view emphasised by Francis Bacon, and illustrated by the early stages in so many aspects of progress. Mr. Turner, in quest of a time marking the maturation of "science teaching" to the "self-conscious stage," tells that "this may perhaps be placed at the middle of the nineteenth century" (p. 189). On p. 191 we are told that the "human side of science is perhaps best introduced by a carefully selected historical treatment." We pass many matters in leaping from Newton on p. 17 to p. 79, where we read of that middle of the scientifically fruitful nineteenth century which the author regards as the self-conscious stage; also, by implication, the human period. We first think of that great event, the 1851 Exhibition, as marking the middle of the nineteenth century, but the actual event which pertains most to the scope of the book may be the establishment and governmental acceptance of the College of Chemistry in Oxford Street with Hofmann as Professor. Turning over to p. 80, we read of W. H. Perkin and H. E. Armstrong working under Hofmann; he being rather a working companion of his pupils, helping them to put questions to nature in the spirit of Bacon, than a formal or dogmatic teacher; but on the next page we read of conditions calculated to culture self-consciousness among teachers, such as money rewards for successes of pupils at examinations; also lectures on the teaching of chemistry (Frankland), and on the teaching of experimental physics (Guthrie). These must have tended to make the teachers intensely self-conscious as regards the teaching function, a tendency which seems to be strengthened by sequences to, or outcomes of, the Elementary Education Act of 1870. Among these outcomes may be mentioned various compulsions and notably the compulsion recorded at the end of p. 149.

One of these subsequent events, however, strikes a somewhat different note, making a concord between teacher and pupil as being fellow investigators. Armstrong, the veteran labourer in all branches of chemistry, has written a book on "Teaching of Scientific Method," and Mr. Turner's section, commencing on p. 142, headed, "The Heuristic Method," embodies the teachings of Armstrong, which may be summarised as doing, for the joy of discovering or knowing; a view which accords completely in spirit with the definition of science given by Aristotle in his *Ethics* (cf., Jelf's text of the *Ethics*, Oxford, 1856, pp. 109-110.) As a comment on his definition of science, Aristotle concludes with a remark to this effect:—Unless the principles are understood even more thoroughly than the conclusion, the science will be accidental rather than fundamental. Vitruvius, who wrote on mechanics, chemistry and many aspects of engineering, takes a similar view as to the difference between scientific knowledge and casual information. In his treatise entitled *De Architecturâ*, written at Rome in the time of Julius Cæsar, Vitruvius tells us the story of Archimedes, and how he in joy of realising a fundamental principle and its application to a problem which then interested the King and the leading men of Syracuse, was so moved by the joy of discovery

that he ran all the way from the baths to his home crying Eureka! Eureka! Eureka! (I have found! I have discovered! I have understood!) The English language long ago accepted "eureka" as a diction in the Greek senses; hence the new or unfamiliar term "Heuristic" may have tended to break or weaken the link with Archimedes. The introduction of the aspirate may please Hellenists who bend towards the Alexandrian period, but must offend students who hold to that decision of the Athenian Grammarians which is mentioned on p. 181 of Liddell and Scott's *Lexicon*: Oxford. Ed. of 1852. Mr. Turner gives us a good general account of Armstrong's method; with knowledge and understanding as its lure and reward, but on p. 145 tells us that "unfortunately the disciples of Armstrong went too far. They regarded practical work in the school laboratory as an end in itself." After this we are told of schoolmasters who were "afraid to tell their pupils anything," also of "unfortunate young investigators" gaining "a marked distaste for the subject." This suggests that teachers have not only failed to realise the essentials set forth by Armstrong, but have mistaught. Possibly the failures may be largely due to increasing self-consciousness, this being stimulated by the change over from special School Boards to the Local Authorities elected for general purposes, as explained on p. 121.

Mr. Turner's volume is so concise, lucid and full of detail that it stands alone among works required by those interested in scientific education.

GENERAL NOTE.

INTERNATIONAL PEAT CONGRESS AT LAON (AISNE) —The first international peat congress will be held at Laon, Aisne, France, from the 8th to 12th July. The programme of the Conference, which is under the patronage of the Minister for Agriculture of the French Republic, will include the reading and discussion of papers, an exhibition illustrating methods of extraction and the treatment and utilisation of peat, controlled experiments and a peat-cutting competition. The text of papers and applications for exhibiting space should be sent in before June 1st to the Secretary, Congrès International de la Tourbe, à l'Office National des Combustibles Liquides, 85, Boulevard du Montparnasse, Paris (6^e), to whom application should be made for any further information on the subject of the Conference.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, MAY 14. Chemical Industry Conference, at the Institution of Civil Engineers, Great George Street, S.W. 10.30 a.m. Sir Arthur Duckham, "The Fuel Industries and the Work of the Chemical Engineer." Prof. G. T. Morgan, "The Chemical Study of Low Temperature Tar." 2.30 p.m. Sir Alexander Houston, "Water Purification"; Mr. J. H. Coste, "The Pollution of Tidal and Non-Tidal Streams."

East India Association, at Caxton Hall, Westminster, S.W. 3.30 p.m. The Maharajahdiraja of Burdwan, "Indian Reform: Past and Future."

Geographical Society, Lowther Lodge, Kensington Gore, S.W. 5 p.m. Colonel Sir Henry Lyons and others, "Notes on Early Geographical Instruments."

University of London, at King's College, Strand, W.C. 5.30 p.m. The Rev. Dr. R. S. Franks, "The Metaphysical Justification of Religious Experience." (Lecture II.)

5.30 p.m. Prof. J. E. Neale, "The Diplomatic Envoy."

5.30 p.m. Mr. H. Wickham Steed, "The Prelude to the War." (Lecture III.)

At University College, Gower Street, W.C. 5 p.m. Prof. Dr. G. Dawes Hicks, "Ruskin's Theory of Art." (Lecture II.)

5.30 p.m. Dr. E. A. Baker, "Rossetti, the Poet."

TUESDAY, MAY 15. Asiatic Society, at the School of Oriental Studies, London Institution, Finsbury

Circus, E.C. Mr. C. Leonard Woolley, "The Excavations at Ur, 1927-8."

Chadwick Public Lecture, at the British Medical Association, Tavistock Square, W.C. 8.15 p.m. Major Walter Elliot, D.Sc., M.P.—"Sunlight—Natural and Manufactured—and its Use in Modern Medicine."

Chemical Industry Conference, at the Institution of Civil Engineers, Great George Street, S.W. 10.30 a.m. The Right Hon. Sir Alfred Mond, "Scientific Research as applied to Industry"; Sir John Russell, F.R.S., "The Part played by British Workers in the Application of Fixed Nitrogen to the Soil." 2.30 p.m. Lt.-Colonel G. T. Pollitt, "Developments in the Heavy Chemical Industry."

Physics, Institute of, 1, Lowther Gardens, South Kensington, S.W. 4.30 p.m. Sir Frank Dyson, M.A., D.Sc., F.R.S., Presidential Address, "Physics in Astronomy."

Statistical Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 5.15 p.m. Mr. D. Caradog Jones, "The Cost of Living of a Sample of Middle-Class Families."

Welding Engineers, Institution of, at Caxton Hall, Westminster, S.W. 7.30 p.m. Mr. P. L. Roberts, "Standardization of Welding."

University of London, at Guy's Hospital Medical School, St. Thomas's Street, S.E. 5 p.m. Prof. J. B. Leathes, "The Human Kidney and the Physiological Study of Human Urine." (Lecture I.)

At King's College, Strand, W.C. 5.30 p.m. Señor Don F. J. Sanchez Canton, "The Life of Goya" (in Spanish).

At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Prof. S. D. Wicksell, "Some Aspects of Population Problems." (Lecture I.)

At University College, Gower Street, W.C. 5 p.m. Prof. Laurence J. Henderson, "Blood, a Study in General Physiology." (Lecture I.) 5.30 p.m. Prof. Halvdan Koht, "Henrik Ibsen." (Lecture II.)

WEDNESDAY, MAY 16..Faraday Society, at Burlington House, W. 8 p.m. Annual General Meeting. Prof. C. H. Desch, Presidential Address, "Diffusion in Solids."

Meteorological Society, 49, Cromwell Road, S.W. 5 p.m. (1) Sir Gilbert Walker, "On Periodicity and its existence in European Weather." (2) Mr. David Brunt, "Harmonic Analysis and the Interpretation of the results of Periodogram Investigations." (3) Dr. C. E. P. Brooks, "Periodicities in the Nile Floods."

Microscopical Society, 20, Hanover Square, W. 7.30 p.m. (1) Dr. H. Moore, "The Mode of Formation of the Image in the Microscope." (2) Mr. G. F. Marrion and Dr. A. S. Parkes, "The Effects of Inanition and Vitamin 'B' Deficiency upon the Testes of the Pigeon." (3) Miss M. E. Shaw and Dr. F. W. Rogers Brambell, "An Aberrant Ovary in a Frog."

Optical Society, at the Imperial College of Science and Technology, South Kensington, S.W. 7.30 p.m. Prof. G. W. Ritchey, "The Modern Reflecting Telescope." (Thomas Young Oration.)

University of London, at Guy's Hospital Medical School, St. Thomas's Street, S.E. 5 p.m. Prof. J. B. Leathes, "The Human Kidney and the Physiological Study of Human Urine." (Lecture II.)

At the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. Dragatin Subotić, "Serbo-Croat Literature of the 15th-18th Centuries, with reference to Italian Influence." (Lecture I.)

At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Prof. S. D. Wicksell,

"Some Aspects of Population Problems." (Lecture II.)

5 p.m. Dr. Hubert Hall, "Some Common Factors in the Economic and Social Development in Medieval and post-Medieval Times." (Lecture III.)

At University College, Gower Street, W.C. 5.30 p.m. Prof. W. Ashburner, "The Ecclesiastical Jurisdiction in England in the 16th, 17th and 18th Centuries."

THURSDAY, MAY 17..Chemical Society, Burlington House, W. 5.30 p.m. (1) Mr. F. M. Hamer, "Neocyanine." (2) Mr. I. Vogel, "Syntheses of Cyclic Compounds. Part III. The Reduction of some Unsaturated Cyano-esters with moist Aluminium Amalgam. A new Synthesis of Mono-Substituted Malonic Acids and of $\beta\beta\beta'\beta'$ -Tetramethyladipic Acid. Further Evidence for the Multiplanar Configuration of the Cycloheptane Ring." (3) Messrs. F. Fichter and E. Brunner, "The Action of Fluorine upon Aqueous Solutions of Chromium and Manganese Salts."

Mining and Metallurgy, Institution of, at Burlington House, W. 5.30 p.m. Annual General Meeting.

Royal Society, Burlington House, W. 4.30 p.m.

Tropical Medicine and Hygiene, Royal Society of, 11, Chandos Street, Cavendish Square, W. 8.15 p.m.

University of London, at King's College, Strand, W.C. 5.30 p.m. Señor Don F. J. Sanchez Canton, "The Paintings of Goya" (in Spanish).

5.30 p.m. Mr. E. H. Warming, "Greek Merchants in India from Augustus to Constantine."

At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Dr. Elie Halévy, "Foreign Affairs and Public Opinion—A Plea for Secret Diplomacy."

At University College, Gower Street, W.C. 5 p.m. Prof. Laurence J. Henderson, "Blood, a Study in General Physiology." (Lecture II.)

5.30 p.m. Prof. Halvdan Koht, "Henrik Ibsen." (Lecture III.)

FRIDAY, MAY 18..Geologists' Association, at University College, Gower Street, W.C. (1) Messrs. A. J. Bull and I. G. Jardine, "A Section in Drift North of Upminster, Essex." (2) Miss B. R. Sauer, "On some Features of the Taplow Terrace between Charing Cross and the Valley of the Fleet." (3) Mr. E. Ernest S. Brown, "On an Unusual 'Pine' in the Blackheath Beds at Bromley Hill." (4) Dr. S. W. Wooldridge, "An Unmapped Outlier of the Boyn Hill Terrace at Herne Hill." (5) Mr. F. Gossling, "A New Section in the Blackheath Beds of the Addington Hills."

Industrial Psychology, National Institute of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 5.30 p.m. Messrs. F. M. Earle and A. Macrae, "Choosing a Career."

Royal Institution, 21, Albemarle Street, W. 9 p.m. Mr. Morley Roberts, "The Sea in Fiction."

University of London, at the Imperial College of Science and Technology, South Kensington, S.W. 5.30 p.m. Sir William J. Pope, "Recent Progress in Stereochemistry." (Lecture I.)

At the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. Julian Krzyzanowski, "Polish Culture in the Middle Ages." (Lecture II.)

At King's College, Strand, W.C. 5.30 p.m. Mr. R. G. Collingwood, "Roman Britain and Recent Excavations." (Lecture I.)

5.30 p.m. Prof. Denis Saurat, "Contemporary Provençal Poets." (in French). (Lecture III.)

At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Prof. S. D. Wicksell, "Some Aspects of Population Problems." (Lecture III.)

At University College, Gower Street, W.C. 5 p.m. Prof. Laurence J. Henderson, "Blood, a Study in General Physiology." (Lecture III.)

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VOL. LXXVI.

FRIDAY, MAY 18th, 1928.

*All communications for the Society should be addressed to the Secretary, John Street
Adelphi, W.C.(2.)*

NOTICES.

NEXT WEEK

TUESDAY, MAY 22nd, at 4.30 p.m. (Dominions and Colonies Section.)
CAPTAIN SIR CECIL ARMITAGE, K.B.E., C.M.G., D.S.O., late Governor and
Commander-in-Chief of the Gambia Colony and Protectorate, "The Gambia
Colony and Protectorate" (illustrated by lantern slides). LIEUT.-COL. THE
RIGHT HON. SIR MATTHEW NATHAN, P.C., G.C.M.G., LL.D., formerly Governor
of the Gold Coast, will preside.

Tea will be served in the library from 4 p.m. before the meeting.

TWENTY-FIRST ORDINARY MEETING.

WEDNESDAY, MAY 9th, 1928. PROFESSOR R. STENHOUSE WILLIAMS, M.B.,
C.M., B.Sc., D.P.H., in the Chair.

A paper on "The Sterilisation of Milk" was read by CAPTAIN REGINALD
WILLINGTON LANE. The paper and discussion will be published in the
Journal dated June 29th.

PROCEEDINGS OF THE SOCIETY.

SIXTEENTH ORDINARY MEETING.

WEDNESDAY, MARCH 14TH, 1928.

WILLIAM MCCLELLAND, ESQ., C.B., O.B.E., M.I.E.E., Director, Electrical
Engineering Department, Admiralty, in the Chair.

THE CHAIRMAN said that Mr. Brown's work and his publications on secondary
batteries were probably as well known to most of those present as they were to
himself, and therefore he needed no introduction. His subject that evening

was one of very great importance, not only to members of the electrical profession, but to the general public, and it gave him much pleasure to call upon Mr. Brown to read his paper.

The following paper was then read :—

THE LEAD ACID CELL.

ITS PLACE IN MODERN INDUSTRY.

By HAROLD G. BROWN, A.M.I.E.E., of The D. P. Battery Co., Ltd.

PART I—HISTORICAL.

INTRODUCTION.

The average man's knowledge of and interest in the lead acid accumulator begins and ends with the part it plays in lighting his country house, starting his car engine and working his wireless set. All these three services are, doubtless, important, and, so far as the last two are concerned, even impressive from the point of view of the number of cells in use.

For every car put on the road a lead acid battery weighing on the average over half a cwt. goes with it. This alone is a big industry and a rapidly increasing one. The output of cells for wireless work has also grown to a remarkable size during the last three or four years. With this aspect of the lead-acid cell we are all fairly familiar, but it is not generally realised, perhaps, how increasingly important a part it is playing in its technical applications to modern industry. It is with this rather less familiar side of the subject I propose to deal. The subject is a wide one and it would be impossible in a paper of this scope to cover the whole ground in any detail. I am, therefore, making only the barest reference to the technical and theoretical aspects of the lead cell and confining myself to some of its more important modern industrial applications.

The Lead Acid Cell.

THE ORIGIN OF THE LEAD ACID CELL.

No method has yet been discovered of storing electricity direct so that it can be drawn upon in controlled amounts as and when required. However, the problem of electrical storage was solved in an indirect manner nearly seventy years ago. Plante was engaged on it in 1859 and wrote a book entitled "The Storage of Electric Energy." He achieved a solution of the problem by first transforming electrical energy into chemical energy and storing it as such through the medium of a galvanic cell.

Before the invention of the dynamo, which enabled mechanical energy to be directly converted into electrical energy, the only method of producing a current of electricity was by the use of some kind of galvanic cell.

In the first half of the nineteenth century the thin trickle of electricity which was the most that could be obtained from even the largest primary cell was all that the investigators and students of electrical phenomena had at their disposal. It was the era of the galvanic cell, and many types were evolved—the lead acid cell among them. Even in those early days the lead cell had a significance of its own, due to two valuable characteristics which set it apart from all other types.

Firstly, it was mechanically and chemically completely reversible, and could thus be used to store the energy produced by primary cells. Secondly, its internal resistance was low, so that enormous currents (judged by the standards then prevailing) could be drawn from it without reducing its voltage to insignificance.

These special characteristics, the importance of which could then be only dimly realised, account for the fact that the lead acid cell is the only surviving galvanic cell which retains any serious importance as a power unit under modern industrial conditions.

There are many theoretically possible alternatives to the lead-lead peroxide couple, but only one has so far achieved any commercial success—viz.: the Iron-Nickel Alkali Cell—a much later invention.

The two types do not come into any very general competition with one another.

The sphere of the alkali cell broadly stated is limited to those services where its lightness and greater mechanical strength off-set its higher cost and lower efficiency. The lead-acid cell owes its supremacy to its comparative cheapness, high efficiency and the flatness of its discharge voltage curve.

PLANTE AND FAURE TYPES.

There are two well-defined types of lead-cell, the Plante type and the Faure type. Both depend for their action on the potential difference which exists between lead and lead-peroxide in sulphuric acid solution. Plante discovered that by passing a current of electricity between two strips of lead suspended in a sulphuric acid solution and by continually reversing the direction of the current he could in time produce a skin of lead-peroxide on one electrode and a skin of chemically porous or sponge lead on the other. Such a cell would possess almost negligible capacity, but by using a sufficient number of sheets of lead and by suitably laminating or corrugating them, so as to expose a large area of lead to the electrolyte a respectable amount of capacity could be obtained. The modern Plante type plate differs in no fundamental respect from this simple early type.

Faure attacked the problem in a different manner. Instead of producing the active material of the cell from metallic lead by a long and costly series of current reversals he constructed light grids, consisting of a framework of intersecting ribs, into the interstices of which he pressed a paste composed of

one or more of the oxides of lead and a solution of sulphuric acid. The plates thus pasted were allowed to dry and set, and then immersed in a sulphuric acid electrolyte and "formed" by passing a current between them in one direction only. The lead oxide paste in the plate or group of plates connected to the positive source of current became converted to peroxide of lead, while chemically porous or "sponge" lead was formed in the plates connected to the negative source.

Thus the same result was finally attained as by Plante's process, but in a twentieth of the time, and with an expenditure of but a fraction of the electrical energy. Faure's cells were not only cheaper to produce, but had from two to three times the capacity of a cell of the same size and weight formed by Plante's original process.

Great expectations were aroused by the initial success of Faure's methods, and it was confidently expected that the more tedious and costly Plante process would be ultimately displaced by the new invention.

These anticipations were not, however, fulfilled. Faure's methods produced an excellent negative plate, but were not so successful with the positives. Experience soon proved that the life of the pasted positive was short compared with the life of the Plante type, and its use was restricted to services where its light weight and high capacity compensated for its comparatively short life. Moreover, it was found that by adding one of the lead dissolving acids, or basic salts of such acids, to the electrolyte during formation, it was possible to abridge Plante's process, so as to put it on a practicable commercial basis. This was sufficient to establish the complete supremacy of the Plante type cell for every kind of work in which durability was the primary consideration, and where size and weight within reasonable limits could be ignored.

During recent years, however, considerable attention has been paid to the high capacity cell with pasted plates. By improvements in design and in the preparation of the active materials the problem of counteracting the fatal defect of the pasted type positive plate—viz., the tendency of the lead peroxide paste to soften and disintegrate—has been attacked with a gratifying measure of success. On a conservative estimate the expectation of life of a Faure type cell has been more than doubled during the past ten years. I might mention that two prominent makers now give three years' guarantee with their traction type cells.

Fig. 1 represents the latest practice in the design of large stationary cells of the Plante type, while Fig. 2 shows a fairly representative Faure cell of the high capacity portable type suitable for traction work. The element is partly withdrawn from the container to show the assembly of the plates.

It will be seen that in the case of the "stationary" cell the container consists of wood with a sheet lead lining. For "portable" cells it is usual to employ some acid-resisting compound of good dielectric properties such as hard rubber

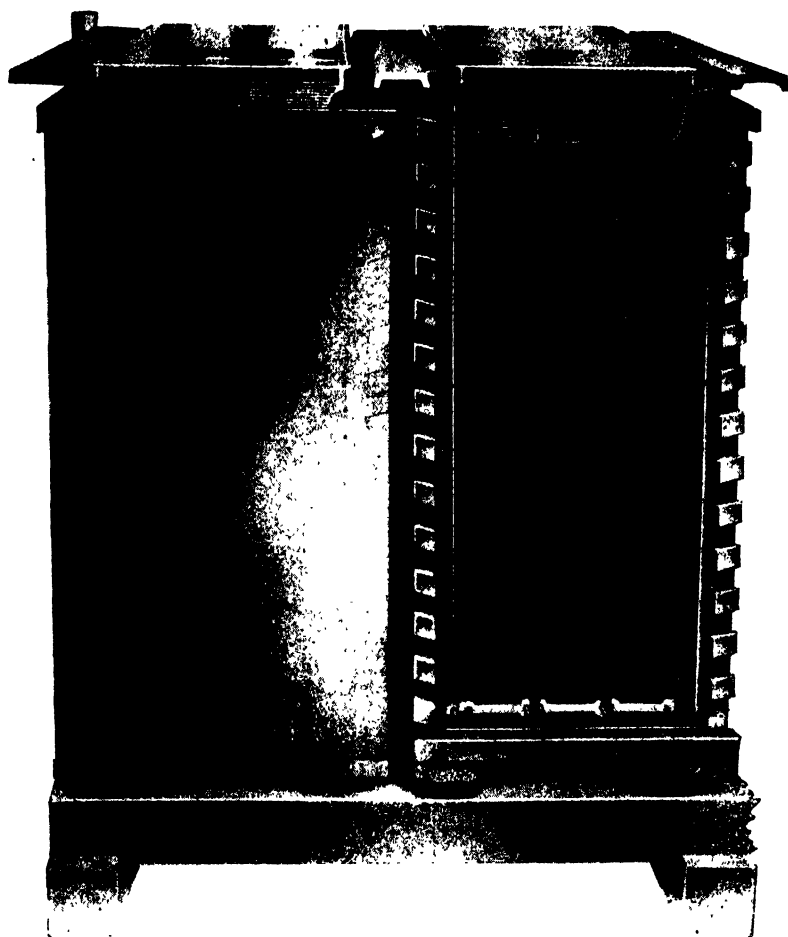


FIG. 1.—Cells in Wood Lead-Lined Boxes.

or the like. This is essential, as owing to limitations of space these cells usually have to be packed closely together, and then considerable differences of potential may occur in a small compartment.

The following table will give a rough idea of the comparative weights of Plante and Faure cells of modern design.

TYPE OF CELL.		CAPACITY PER POUND.
Plante (heavy)	— 3.1	watt-hours per lb. of cell.
„ (light)	— 3.75	do.
Faure (heavy)	— 9	do.
„ (light)	— 10-12	do.

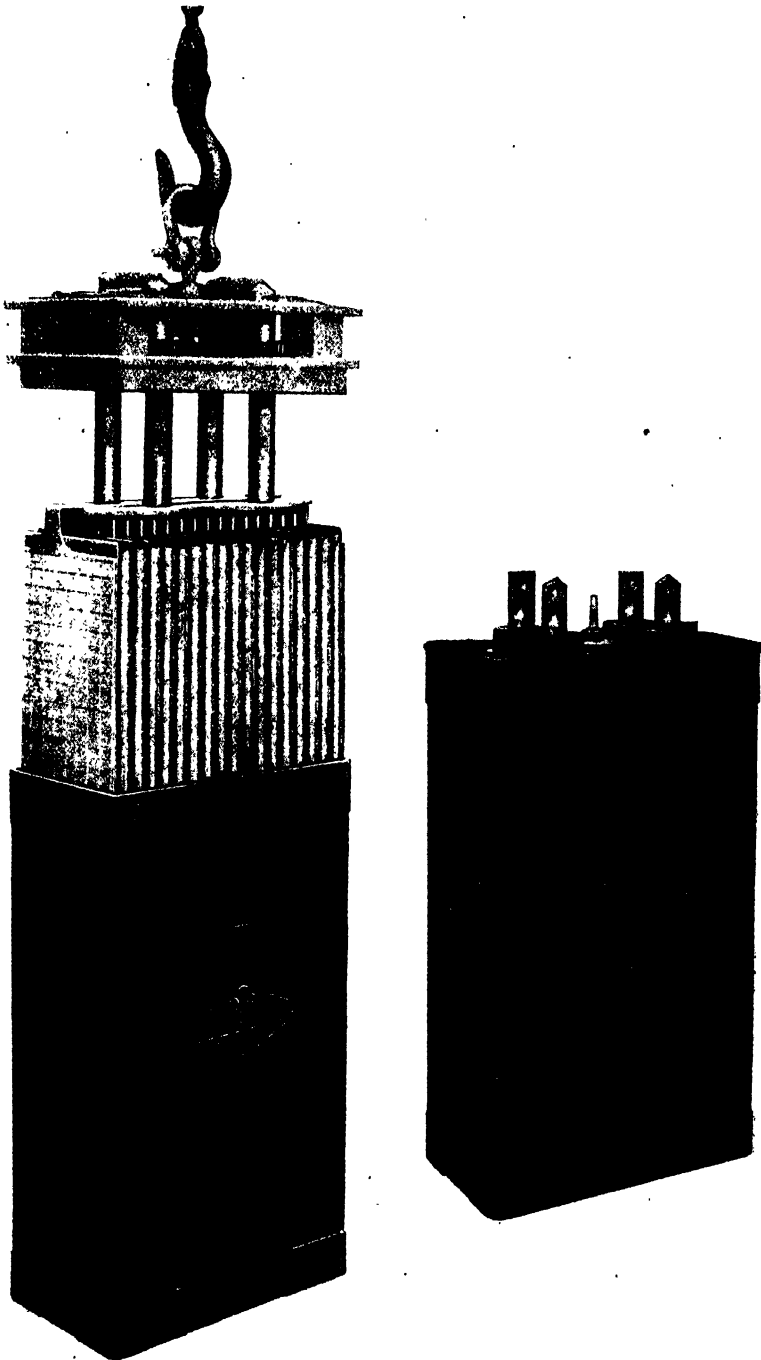


FIG. 2.—Katharode Cell with Element partly withdrawn.

PART II.—THE LEAD ACID CELL AS A POWER UNIT.

Undoubtedly the invention of the lead acid battery gave a great impetus to the electrical industry by making what I may term the domestic production of electricity in small plants of the country house type a practicable undertaking.

A natural development rendered possible by improved manufacturing technique was the realisation of the economies which could be effected by storage batteries in large installations. In generating stations of considerable size, where the load is sufficient to keep the plant running pretty well continuously, the function of the battery is to level out variations in the demand so as to enable the generators to run steadily at their most economical load. There are indications to-day which rather point to the possibility that this is a passing phase in the history of storage battery engineering. The distribution of high tension alternating current over wide areas, from a comparatively few super-power stations, will tend to eliminate the local production of electricity except in remote or thinly-populated districts. However, this time is not yet, and the—by comparison—small local generating station is still with us and will probably play an important part in the industrial life of this country for many years. I think it, therefore, worth while to devote a short space to a consideration of the principles underlying the use of batteries in direct current stations, before passing to some of their more modern and specialised uses.

CENTRAL STATION BATTERIES.

Fig. 3 illustrates the kind of service performed by a battery in the ordinary Central Station of moderate capacity. The peak of the load is cut off by the discharge of the battery while the valleys in the load are filled up by charging the battery, the generating plant being kept running on a steady continuous load.

The considerations which influence the installation of a battery plant in a Central Station may be briefly stated as follows: It is required

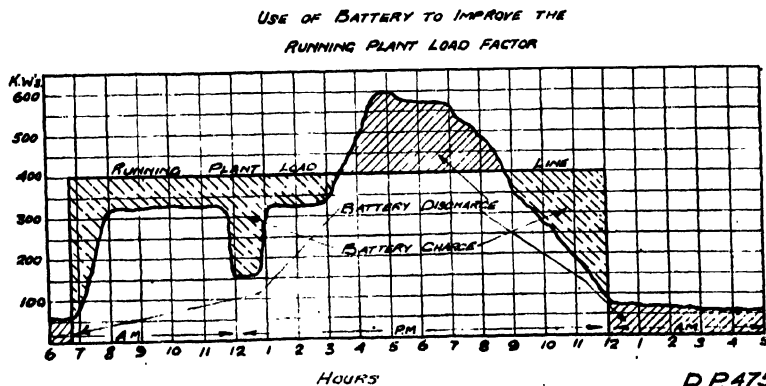
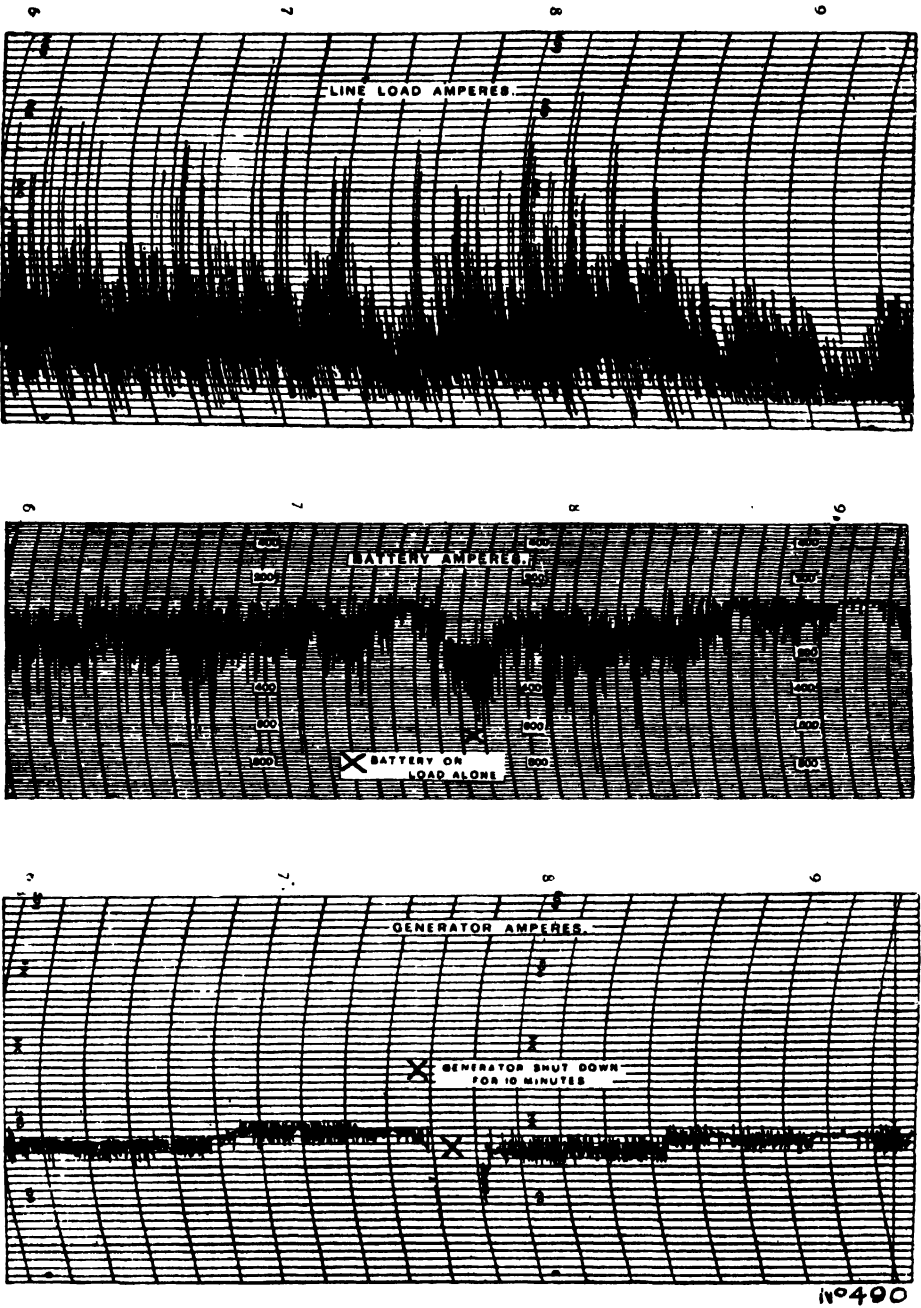


FIG. 3.—Load Factor Curve.



LOAD REGULATION BY BATTERY AND AUTOMATIC BOOSTER PLANT.

FIG. 4.

- (1) To act as a standby in the event of the failure of a generating set.
- (2) To cope with sudden unexpected demands.
- (3) To enable the generators to be shut down during periods of very light load, and
- (4) Generally to improve the running plant load factor on which the efficiency of the Station principally depends.

So far as (1), (2) and (3) are concerned, the value of the services performed by a battery is obvious, but with regard to (4) some explanation may seem called for.

The energy efficiency of a lead acid cell is about 75%, in other words, it is necessary to put 100 units into a battery in order to take out 75 units later on. It is not, therefore, self-evident that it can be an economy to use a battery to improve the running plant load factor on the lines indicated in Fig. 3. This is an argument which is often used against the installation of batteries, and as a good deal of misconception exists on the subject it is worth a few moments consideration.

The important point to bear in mind is that the battery charge is obtained by loading up generating plant which would have to be kept running in any case. The units thus produced are cheap because they can be obtained for just the cost of the extra fuel consumption entailed by raising the load on the generating plant, and this cheapness more than counterbalances the loss of 25% of them. Such items as wages, repairs and maintenance, engine-room stores, oil, water, waste, etc., are not affected by the increased output of the generating plant, and the units thus produced should not be debited with these costs. Thus it follows that with a running plant load factor of anything much less than 100%, it will pay to load up the sets to full load by charging the battery on the lines indicated in Fig. 3. It may be taken that if the capacity of the storage plant is determined with due regard to the shape of the load curve of the station and the size of the generating units, substantial economies can be effected. (*See Appendix A*).

A Power load of a totally different character is illustrated in Fig. 4. The load charts are reproduced from the original recording ammeter charts taken during the operation of a 500 volt plant supplying an installation of electric coaling cranes. The plant consists of 2-100 K.W. suction gas generating sets, a 1,000 ampere-hour battery and an automatic reversible booster. The actual mean load on the station is just within the capacity of one generating set, but the peaks of the load which occur every few minutes are more than four times the value of the average load. The charts are self-explanatory. It will be noted that the generating set runs at nearly full load, the variations not exceeding 15 amperes above or below the mean. This is a very striking example of what is sometimes called "buffer" work. It is little less than a revelation to note the astonishing flexibility which can be imparted to a power plant

by a battery and automatic booster installation. In this particular plant there are five electric cranes. By running both generating sets, as an experiment, it was found possible without the battery to operate three cranes simultaneously, but in a very unsatisfactory manner. Even with three cranes the violence of the fluctuations in the load, which occasionally fell almost to zero and in a few seconds was up to between 600 and 700 amperes, was more than the engine governors could cope with and was reflected in irregular engine speed, harsh running and hunting. With the battery and booster on the line one generating set will deal comfortably with four cranes, and the most violent surges on the line load create little more than a ripple in the generator load. In this kind of work the special characteristics of the lead-acid cell are of particular value. A comparatively small lead battery is capable of yielding very heavy currents for short periods without excessive voltage drop. This is particularly true of the Plante type, owing to the large superficial area of plate exposed to the electrolyte.

The part played by the storage battery in the typical cases I have just described might be termed its traditional or conventional role, and it is difficult to see how the sort of load represented by the charts in Fig. 4 could possibly be dealt with by bulk supply so satisfactorily as by a local plant with a storage battery and automatic booster. It is doubtful whether sufficient consideration has been given to the possibilities of combining the advantages of bulk supply with the economy and flexibility of a battery plant. It is, of course, greatly to the advantage of supply companies to avoid big peaks or violent fluctuations in their transmission line loads, and this is naturally reflected in the rates they charge consumers. It should certainly be worth the while of any power user who is contemplating taking a supply from a Power Company's mains to give careful consideration to the possibility of getting better terms by installing a battery and improving his load factor. It should be equally in the interests of the supply companies to encourage consumers in this course. This is a matter which cannot be discussed adequately in a paper of this scope, and I only refer to it in passing.

PART III.—MODERN DEVELOPMENTS.

If in some directions storage batteries appear to be losing ground there are other directions in which they can record very substantial gains. It is rather interesting to note that the situation, so far as batteries are concerned, seems to be developing in directions where their use is dictated not primarily by economic reasons but by technical necessities. As it is impossible in the time at my disposal to cover the whole ground, I have tried to select a few representative examples which will best afford an idea of the developments which are taking place in storage battery engineering and the indication they afford of future possibilities.

Post Office Work.

Among the largest individual users of the lead acid storage battery is the Post Office ; it was also, as it happens, one of the earliest.

It will probably surprise most people to learn that in the size of its individual units the storage plant in a modern telephone exchange is about the largest at present manufactured. The largest single battery installed at the present time consists of 22 cells of 10,000 A.H. capacity, but in time it is anticipated that batteries of upwards of 20,000 A.H. will be required. By kind permission of Col. T. F. Purvis, Engineer-in-Chief of the General Post Office, I am able to quote the following figures relating to storage battery plant either at present installed, or of which the installation is projected during the next five years.

The present capacity of secondary cell batteries installed in Telephone Exchanges and Repeater Stations is :—

(a) London—13,560 K.W. hours.

(b) Provinces—14,890 K.W. hours.

The largest single battery at present installed is 50 volts 10,000 A.H. During the next five years the installation of 50 batteries of this size is contemplated. It is estimated that by 1932 the capacity of secondary batteries installed in Telephone Exchanges and Repeater Stations will be :—

(a) London—26,650 K.W. hours.

(b) Provinces—49,700 K.W. hours.

Thus it is estimated that during the next five years the total capacity of Post Office Battery installations in London and the Provinces will increase from their present figure of, in round figures, 28,500 K.W. hours to 76,350 K.W. hours. Ultimately batteries of upwards of 20,000 A.H. will be required. It is probable that the demand for batteries of this capacity will be met by parallelling two batteries of 10,000 A.H. capacity, so as to avoid the mechanical difficulties in the construction and erection of a single cell of this capacity. Some data with regard to the size, weight and construction of a typical cell as used in a Telephone Exchange installation may be of interest.

As usual for stationary installations a Plante type cell is used, *i.e.*, Plante positives, combined with box type negatives. The particulars of a typical cell of about 10,000 A.H. capacity are approximately as follows :—

DIMENSIONS.

Positive plate $20\frac{1}{2}" \times 29" \times \frac{1}{2}"$ thick.

Negative plate $20\frac{1}{2}" \times 29" \times \frac{3}{4}"$ thick.

The cell complete $47" \times 27\frac{1}{2}" \times 54"$ high.

WEIGHTS.

Positive plate, $75\frac{1}{2}$ lbs. (23 in number).

Negative plate, $39\frac{1}{2}$ lbs. (24 in number).

Cell complete with acid about $2\frac{1}{4}$ tons.

The volume of acid—about 125 gals. of a specific gravity of 1.215.

The construction of the cell is substantially as illustrated in Fig. 1. The plates are supported in the usual manner by suspension from vertical glass slabs. The container consists of well-seasoned timber with a sheet lead lining.

Fig. 5 represents a typical battery of this type installed in the Gloucester Repeater Station.



FIG. 5.—Telephone Repeater Station Battery.

WORKING METHODS.

The function of a battery in a Telephone Exchange and Repeater Station is to furnish a perfectly smooth flow of current free from ripples or other disturbances and at a fairly constant voltage. Some fall in voltage between the beginning and the end of discharge does, of course, take place, but this is small and very gradual owing to the flatness of the discharge voltage curve of the lead acid cell. For instance, in the case of a 22 volt battery, such as is used in the common battery Exchange, the voltage at the commencement would be approximately 22.5 volts, and at the end (presuming full capacity were taken out at the 9 hour rate of discharge) the final voltage would be approximately 20.1 volts. Two independent batteries are used, one supplying the exchange whilst the other is being charged. Experiments have been carried out in order to determine the possibility of supplying the exchange with current direct from a dynamo, but up to the present no satisfactory method of eliminating

ripples in the current due to the effect of the commutator has been discovered. A Homopolar Generator would solve the difficulty, but no successful machine has yet been produced. The present method, therefore, of two independent batteries has been standardised. In the common battery exchange a pressure of 22 or 24 volts is used mainly because the apparatus, especially the microphone, has been standardised to suit this voltage. The automatic system requires 60 volts and the Peel-Conner system 40 volts, but in these cases by the use of Counter E.M.F. cells or apparatus in series the microphone current is brought down to about the same standard value. In a Repeater Station batteries of two different voltages are used, low voltage batteries consisting of 11 cells and high voltage batteries of 75 cells. The low voltage battery supplies the filaments of the valves connected two, or sometimes four, in series, and the high voltage batteries supply the plate current to these valves.

Railway Work.

The Railway Companies are large users of storage cells, principally of the lead-acid type. They are employed for a variety of purposes, such as, for instance, the operation of signals, points and swing bridges, lighting, cooking on restaurant cars, portable lamps, etc., etc. From the point of view of the convenience and safety of the travelling public they are quite an important factor in Railway work.

Their most extensive use is in the electric lighting of trains.

Train Lighting by electricity was first tried by the London Brighton and South Coast Railway Company, in 1881. Thirty-two Faure type cells were used, each weighing about 46 lbs., and capable of supplying current to 12 carbon filament lamps for six hours. In 1883 the same company equipped three trains with electric light; a dynamo in the guard's van driven by a belt off one of the axles supplied current to a battery of lead cells. As a result of these experiments, the electric lighting of trains was proved a practicable proposition and twenty trains of the London, Brighton and South Coast Railway were equipped with electric lighting during the following few years.

The introduction of Messrs. J. Stone & Co's single battery system, in 1894, followed by their double battery system, in 1896, led to the more or less universal adoption of train lighting by electricity in place of gas. The change from gas to electricity was hastened by public alarm at the loss of life caused by the fires which on several occasions broke out among the wreckage after railway accidents.

There are several systems of train lighting, but all necessitate the use of batteries. Both single and double batteries are used, each battery consisting of 12 cells. When double batteries are used one battery is charged from a dynamo driven off an axle of the coach while the other is connected to the lamps. Periodically the batteries are changed over, so that the battery on discharge may receive a charge and *vice versa*. This is usually done by an

automatic device. The cells used for this work must be of the most robust construction. They are carried in a box or boxes attached to the underframe of the coach and are subjected to considerable vibration and shunting shocks, as well as widely-varying rates of charge and discharge. A certain amount of accidental abuse is also inevitable. Lights may be left burning all night in a stationary coach, or a belt may be lost and not immediately replaced.

Both Plante and Faure type cells are used for this work. The necessity for cutting down size or weight to a minimum is not in this case so vital a consideration as the provision of a cell which will function with a minimum of attention for as long as possible. Durability rather than a high capacity-size or capacity-weight ratio is the first consideration. There is, therefore, a good deal of scope for the individual ideas of the battery manufacturer.

Electric Signalling.

An interesting use of lead-acid cells is made in connection with certain types of automatic signalling devices. The apparatus requires an occasional fairly heavy discharge from the cells for a few moments, but most of the time they stand idle. The cells are required to operate at widely scattered points on the railway system and the collection and despatch of the cells periodically to some depot for charging would be altogether too inconvenient and expensive. Primary cells would in some ways be ideal for work of this kind as they would not, of course, require to be charged, but unfortunately, the largest primary cell would be incapable of supplying the heavy momentary currents required to operate the signals owing to its high internal resistance. On the other hand, lead cells, though capable of giving the necessary current without excessive voltage drop, must be recharged periodically.

The problem has been solved by an ingenious arrangement whereby lead cells operate the signals and primary cells gradually recharge the lead cells. A group of lead cells is connected in parallel with a battery of primary cells, the number of cells in the primary battery being sufficient slightly to exceed the normal open circuit voltage of the lead battery. In operation, therefore, the lead battery supplies the large momentary demands of the signalling apparatus while the primary battery continually sends a "trickle" charge into it and thus maintains it in a fully charged condition. I understand that under these conditions it is necessary only to renew the primary cells about every ten months or so.

Further developments in this direction are likely. In place of primary cells the trickle charge may be obtained from A.C. mains by the use of rectifiers. Where D.C. current is required for intermittent or stand-by work, as, for instance, in A.C. generating stations for the operation of switch gear and the like, this method of obtaining it is likely to be extensively adopted.

Submarine Batteries.

Another very important and highly specialised use for lead acid cells is in Submarines.

I need scarcely explain that the main engines of a Submarine cannot be used when the vessel is submerged. She then depends for propulsion upon her batteries and main motors, the latter being mounted on the propeller shafts between the main engines and the propellers. Subject to some minor variations the following arrangement has been more or less universally adopted both in the British and in Foreign Navies. On the surface the engines drive the propellers through clutches on the propeller shafts. The main motors mounted on the shafts are then driven by the engines and can be made to run as generators for charging the batteries; sometimes separate battery charging generators are installed, in which case the main motors would be used purely as propelling motors. When the vessel submerges the engines are disconnected from the propeller shafts by means of the clutches, and the main motors drive the vessel from the storage batteries. The propulsion of the vessel when submerged is, of course, the main function of the batteries, but in addition to the main motors there are a large number of electrical auxiliaries each of which may take anything up to 50 k.w. In fact, the whole vessel is electrically operated, and when the engines are not running everything is worked by the batteries.

The capacity of the individual cells used for submarine work varies in different navies—from about 2,000 A.H. to 10,000 A.H. In several navies the capacity of the individual cell is between 4,000 and 5,000 A.H. It is usual to operate two or more batteries in parallel, thus enabling the size of the individual cell to be reduced and rendering it a more compact and easily handled unit. This not only facilitates the installation or removal of the battery from the submarine but incidentally simplifies the manufacture of the cell, especially the container. Further, this arrangement of batteries in parallel is a safeguard against breakdown, as with two or more batteries in parallel, the chance of a failure of current is remote.

Both on technical and financial grounds the lead acid cell has been universally selected for submarine work, and, so far as can be seen, its supremacy in this direction is not seriously threatened. In the design of a suitable cell, however, a good many problems present themselves, due to the operating conditions prevailing in a submarine and the limitations of size and weight.

Fig. 6 shews a typical submarine cell with the plate groups partly withdrawn from the container to shew the method of assembly. The plates are of the "Faure" or pasted type. At one time Plante positives were commonly used in submarine cells, but the increasing requirements of submarine work have far outstripped the capacity obtainable from this type of positive in the limited space available. The increase in capacity, due to the introduction of a "Faure" type plate several years ago, had the natural result of reducing the life of submarine cells, but there has since been a continuous improvement

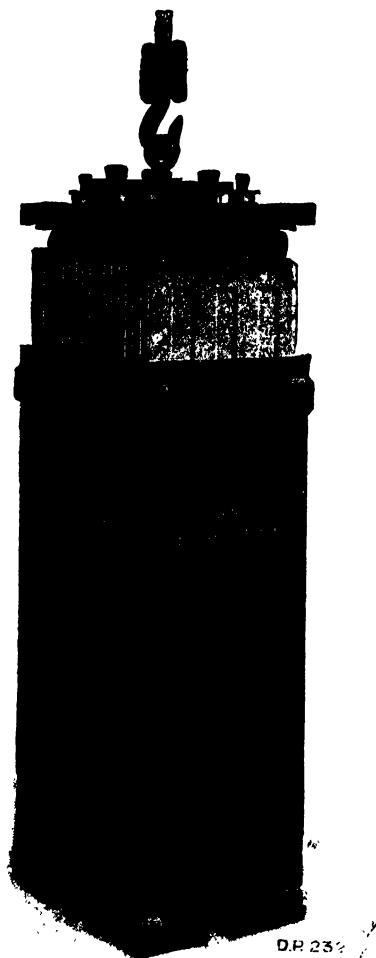


FIG. 6.—Submarine Cell showing details of construction.

in this respect, which is still being maintained. At the present time a reasonable expectation of life for a submarine cell is about 5 years, and this is likely to be increased in the near future.

It will be noticed from Fig. 6 that the plate groups are supported from the lid of the container. The lid is thus held down firmly by the weight of the plates and is sealed to the container by a rubber gasket and some kind of bituminous sealing compound so as to make an acid tight joint. The ventilation of the cell is effected through a vent in the centre of the lid. The capacity of this cell is about 4,000 A.H. and the weight about 900 lbs.

The number of cells installed in a submarine depends, of course, upon the size and type of vessel. About 120 volts for smaller types and 200-240 volts

for large vessels is commonly used. In some Navies a single battery of large cells is used, but more generally two, or in some cases three, batteries are connected in parallel. In large submarines a total battery capacity of between 2,500 and 3,000 k.w. hours, with a weight of between 110 and 150 tons, is installed.

STOWAGE AND VENTILATION.

There are several interesting points in connection with the stowage and ventilation of submarine batteries.

The cells are stowed in battery tanks beneath the floor and wedged up tightly together from the sides of the tank. Distance pieces moulded on the containers hold them apart from one another sufficiently to allow circulation of air round them. These distance pieces are accurately faced so as to ensure a perfectly even bearing between adjacent cells. One of the most difficult problems in connection with the operation of these batteries is the question of ventilation. The roof of the battery tank consists of stout beams to which the deck is bolted in sections so as to form as far as possible a gas tight chamber. The explosive gases produced towards the end of charge in a secondary cell consist of oxygen and hydrogen. The explosion of these gases is very violent, so that it is necessary to provide an adequate ventilation system for drawing off these gases and discharging them to the outer air. One method is to leave the vents in the lids of the cells open to the tank and by means of exhaust fans to withdraw the mixture of air and gas from the tank and discharge it overboard. Sufficient air can thus be mixed with the cell gases to dilute them below danger point. The more modern method used by nearly all navies is to employ what is termed separate cell ventilation; the gas being drawn from each individual cell by a separate pipe connected to the vent hole in the lid, thence being led into ventilating trunks and discharged by fans. These problems do not arise in stationary battery installations, as the dilution of the battery gases is usually sufficient to keep them below danger point.

COMPARATIVE FIGURES.

As an interesting comparison I give some figures relating to a Plante type stationary cell and a portable cell of the submarine type, both of approximately the same capacity in tabular form as follows :—

	Stationary Type.			Submarine Type.		
Capacity at 9 hour						
rate.	...	...	3,800 A.H.	...	...	4,100 A.H.
Weight.	...	...	2,000 lbs.	...	...	920 lbs.
Dimensions.	...	...	40" X 19" X 39" high	...	...	17" X 13½" X 44" high
Watt Hour per lb.	...	...	3.6	...	...	8.4

Battery Traction.

Battery Traction probably offers one of the biggest potential fields for the use of secondary cells. The use of batteries for the propulsion of vehicles is not by any means a new development. In the quite early days of batteries attempts were made to put battery-driven passenger vehicles on the roads, but none of these attempts achieved any commercial success, due to a variety of causes, but principally to battery troubles. The failure of these early attempts, added to a misconception of the proper function of battery-propelled transport, surrounded the whole business in a cloud of prejudice which has been only gradually clearing away during the past 7 or 8 years.

To-day the problem of battery transportation is on an infinitely better footing. In the construction of the chassis of the modern electric vehicle valuable experience gained in the motor car industry has been incorporated. Improvements in the design of controller gear and electric motors, and the production of thoroughly reliable storage batteries, have resulted in a transportation unit which is a sound and economical commercial product and in its own sphere has no rival.

Battery transport may be roughly divided into three main classes.

- (1). Road Transport.
- (2). Locomotives. (a) Standard Gauge.
(b) Small Narrow Gauge.
- (3). Industrial Trucks.

(1.) Road Transport.

Until quite recently the proper function and the real sphere of the battery road vehicle have not been correctly appreciated. It does not, and probably never will, compete with petrol or steam for long distance high speed transport. Its proper sphere is in point-to-point work within a small radius in congested urban districts. For this purpose it is the ideal form of transport, being noiseless, clean, economical and easy to handle. It possesses further the important qualifications of rapid acceleration and good braking.

The situation which has arisen during the last four or five years, due to the enormous growth in the volume of road transport, is providing one of the most insistent and difficult problems with which municipal authorities are faced to-day. The traffic congestion in large towns, particularly London, is threatening to destroy the amenities of life so far as they depend upon quick and comfortable transport, while the nuisance created by the exhaust gases from petrol vehicles is becoming a serious matter. Streets which, as regards road accommodation, have not materially changed during the last 25 years, are now being called upon to deal with a vast and rapidly growing increase in the volume of traffic with which they are quite unable to cope.

No one who has driven a car in London can have failed to observe that one of the principal contributory causes of traffic dislocation is the presence of the horse-drawn vehicle. Horse transport in a city like London is an anachronism which is both costly and unnecessary and should have been forbidden long since. The horse-drawn vehicle not only reduces the pace of the traffic stream by its slow maximum speed, but its meagre powers of acceleration and manœuvring adds to the general dislocation of traffic and increases the delays due to traffic stops and "hold-ups." The work which is now being done by horses in city and suburban transport is the particular field of the electric vehicle. In certain quarters this fact is now well established and is being duly recognised. Almost all large municipalities make extensive use of electric lorries for refuse collection and similar work. Glasgow, Birmingham, Sheffield, and Nottingham, to mention only a few, run large fleets of electric lorries. The city of Sheffield runs no less than 75 of them for refuse collection alone. In this kind of work battery transport is now established on a firm economic basis and requires no kind of special pleading. It is cheaper than petrol, steam or horses, and has the added advantage of being noiseless, clean and easily handled. Private users, however, of the electric vehicle are not so numerous in this country as they might be. In the United States one firm alone (The American Express Co.) employs a fleet of 1,500 electric street* vehicles. In America, however, they have gone further than we have in forbidding horse transport in the central areas of big cities, which no doubt partly explains it, and a further contributory cause is that in America the manufacturers of electric vehicles appear to have paid more attention to the requirements of the potential private user. The tendency in this country in the past has, perhaps, been to concentrate too much on the heavier type of electric lorry, more suitable for municipal departments, and too little on the light delivery van. This matter, however, is being remedied. Two firms of electric vehicle builders at least are now producing a light one-ton delivery van which entirely meets requirements. There is, undoubtedly a big future for battery vehicles in this direction, even if they do no more than occupy the territory now held by horse transport. A powerful stimulus will be administered both to the supply of, and the demand for, a light electric van when (as is bound eventually to happen) horse transport is barred from inner city areas.

I do not think any particular purpose would be served by quoting statistics of the costs of operating electric vehicles as compared with petrol, steam or horses. The accountant's department of dozens of municipal engineers during the past ten years have analyzed the running costs of these various forms of transport with the greatest care and accuracy. The adoption of the battery vehicle by the largest municipalities in this country has only followed the most searching scrutiny of the rival claims of other forms of transport. (See Appendix.)

* Since writing, this number has been increased to 2,000.—*Author.*

In the lighter form of electric transport the lead acid cell meets the competition of the alkali cell. Neither type can claim supremacy, but the lead cell is in more common use.

COMPARATIVE FIGURES—LEAD-ACID AND ALKALI CELL.

The various considerations which influence the choice of either type for any particular service may be tabulated for purposes of comparison as follows, it being understood, of course, that the figures are approximate only and merely intended to afford some idea of the relative positions occupied by the two types. An 80 volt 300 A.H. Battery is a common size and will serve very well as a basis of comparison.

			Lead Battery.			Iron Nickel Battery.
Number of Cells	...	...	40	...	...	60
A.H. Capacity			300			300
Average Voltage on load	...	...	76.5 (40 $\times$ 1.91)	...	...	72 (60 $\times$ 1.2)
Cubic Space	...	...	18 cub. ft.	...	...	19 cub. ft.
Weight of complete Battery			2400 lbs.			1800 lbs.
Life	...	...	3 years.	...	...	6-8 years.
Efficiency	...	...	70-75 per cent.	...	...	55-60 per cent.
Price	...	...	£200	...	...	£600
Speed	...	...	Faster on hills.	...	...	Slower on hills.

(2.) Battery Locomotives.

(a.) STANDARD GAUGE LOCOMOTIVES.

The operation performed by locomotives in shunting service on goods terminals requires a big tractive effort at moderate speeds, and the capacity for rapid acceleration under load. Taken over a whole day the total energy output of the locomotive is comparatively small, but while in actual operation the demands upon it are heavy but intermittent. The characteristics of the lead-acid battery, viz., its capacity to sustain very heavy rates of discharge for short periods renders it specially suitable for loads of this character. No other type of self-contained locomotive of equal weight can develop the same power for short periods as the battery locomotive. This feature, combined with its other characteristics, i.e., noiselessness, ease of operation, economy and cleanliness, open out a very important field for its future use. Although considerable attention has been directed to the storage battery locomotive during the past few years, we are barely on the fringe of the developments likely to arise in the near future. The opinion is generally held that the ultimate electrification of the railway termini in large cities is merely a matter of time. The storage battery locomotive will solve one of the biggest difficulties

likely to be encountered, viz., the extreme complication and expense of electrifying goods yards and shunting yards, whether by trolley wire or third rail. The battery locomotive offers the simplest and most obvious solution of this problem. Matters are already moving in this direction. The Bombay Baroda & Central Indian Railway Co. have two battery locomotives on order in this country for operation at their Bombay Terminus. These locomotives are now under construction by The English Electric Co.* They will be the largest battery locomotives yet built in this country and will be equipped with batteries capable of developing 600 h.p. for starting under load.

In the U.S.A. the largest battery locomotive in the world has recently been put into service. It weighs 110 tons and is capable of hauling a 1,500 ton train from 8 to 10 miles an hour. The battery in this locomotive weighs 39 tons, being the largest ever built for this purpose. It consists of 120 cells with a capacity of 616 K.W. hours and capable of discharging up to 846 K.W. I mention this instance as a remarkable illustration of the potentialities of electric railway traction. In this country, however, the development will not be in the direction of such large units, the operating conditions being totally different from those prevailing in the United States. We can, however, expect to see a great development in the use of battery locomotives of more moderate capacity. In fact they have already become a definite factor in modern transportation. Standard gauge battery locomotives are in use at Electric Power Stations, Gas Works, Engineering Works, and in Railway Goods Yards. Both the War Office and the R.A.F. make use of battery locomotives in Camps and Ordnance Depots.

(b.) SMALL BATTERY LOCOMOTIVES—NARROW GAUGE.

This type of locomotive is of comparatively recent production, but it has proved itself to be both technically and financially a sound proposition. By small locomotive is meant one which is designed to haul loads of from ten to fifteen tons on a narrow, often badly laid track such as is used by contractors in constructional or excavation work or for work in mines or tunnels.

TUNNELS AND EXCAVATION WORK.

Locomotives of this type were first used about five years ago in the London Tube extensions. They proved of the greatest value in expediting the work, which involved shifting immense quantities of excavated material from the workings. Owing to the water-logged nature of the soil the work had to be done in an air-lock, and this was one of the reasons which dictated the use of battery locomotives. Similar conditions were encountered in the constructions of the London Sewage Tunnel, which extends from Shadwell to Highbury. Obviously in this kind of work, which involves air-locks and working in confined spaces, one of the most essential precautions is maintaining the purity of the

* Since the above was written the contract has been completed.

air. Contamination by engine exhausts would be quite inadmissible and forbids the use of internal combustion engines. Horses are undesirable for similar reasons. Battery locomotives, on the other hand, are ideal for the purpose, being self-contained, free from smell or poisonous fumes and very easily handled.

A large fleet of battery locomotives is now at work in the Mersey Tunnel which has been under construction about 18 months. The locomotives are designed to haul 5 tons of excavated material up grades of about 1 in 30. As time in these jobs is the essence of the contract, the locomotives are required to work right round the clock, week in and week out. To enable them to do this each locomotive is equipped with two, or in some cases with three batteries, so that while one battery is at work the other is being charged. This method of operation naturally immensely reduces the overhead charges on the locomotives.

COAL MINES—THE MARKHAM AWARD.

A service analogous to the above is the use of battery locomotives in Coal Mines. The design of the locomotive and the conditions of operation are much the same. In the case of the coal mine locomotive, however, the design must comply with a more stringent specification owing to the danger of fire in certain mines and of "falls" from the roof. A good deal of attention has recently been focussed on the battery locomotive for coal mines by the late Mr. Charles Markham's offer of £1,000 prize for the best designed battery locomotive for use underground in coal mines. The award was open to competition, and the competing locomotives were subjected to exhaustive trials. The winning locomotive was deemed by the judges to fulfil the conditions and was in their opinion the best that was submitted to them. The adjudicators were Mr. J. A. Horseley (H.M. Inspector of Mines), representing the Mines Department, Mr. Roger T. Smith (Institution of Electrical Engineers), Mr. Roslyn Holiday (Mining Association), Mr. Sidney Bates (of the Institution of Mining Engineers) and Mr. Herbert Smith (of the Miners' Federation). I am quoting these names as they represent a body of expert opinion which has set the seal of its approval on the technical soundness of the coal mine locomotive. The production of a satisfactory machine will almost certainly open fresh fields for the use of this method of traction and should assist in reducing costs and improving underground conditions.

The locomotive which won the Markham award, manufactured by Joseph Booth & Bros., Leeds, is shown in Fig. 7. This gives a good idea of the general appearance of the small battery locomotive suitable for surface or underground work. The batteries are contained in two steel receptacles mounted on the chassis, so arranged that each group can be rolled in or out, thus enabling an exhausted battery to be removed and a fully charged one put in its place, the total operation taking only three minutes. This locomotive

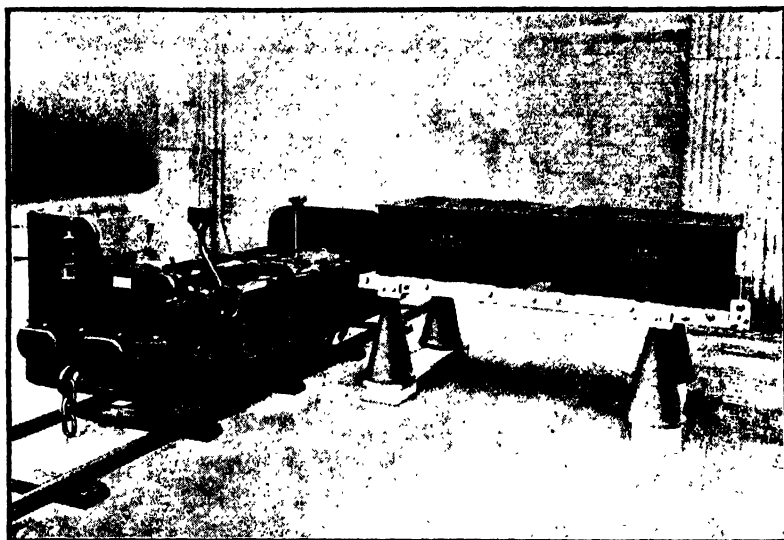


FIG. 7.—Mining Locomotive.

weighs 3.15 tons and is capable of drawing a 5 ton load up a 1 in 25 gradient at $5\frac{1}{2}$ miles per hour. The maximum speed on the level is approximately 9 miles per hour. The lead acid accumulator is almost exclusively used for this type of work. Weight is not a vital consideration, but a high ratio of capacity to cubic content is of primary importance. The use of the Faure type high capacity pasted cell is, therefore, demanded by the limitations of space rather than weight. As a general principle it is advisable to keep the voltage of the battery as low as is consistent with the satisfactory operation of the motors. The number of cells should not, therefore, exceed 40, and may with advantage be much fewer. Satisfactory operation with 20 cells is quite possible. The success of these vehicles depends largely upon their fool-proof qualities—they must be as simple and robust in construction as possible. A low voltage battery is of material assistance in this direction.

Post Office Tube Locomotives.

Running from Paddington to Whitechapel through 6 intermediate stations is a miniature tube railway built by the Post Office for the transport of letter and parcel mails between the principal post offices and railway stations in London. The scheme was projected before the war, but is only just now nearing completion.

The tunnels between stations are 9 ft. 0 ins. in diameter, opening out to 25 ft. 0 ins. in Stations. The stations are situated immediately beneath or close to the District Offices, from which special shoots deliver parcels from the sorting offices to the railway platforms. Here they are loaded on to trains

consisting of three cars each, equipped with a power unit operating by means of a third rail on 440 volts D.C. between stations and 150 volts within station limits.

Lead accumulators play an important part in the equipment of the railway. The operation of the railway is automatic—the trains have no drivers. The brake magnets are in series with the motors and are thus held off so long as the train is on a “live” section, and are automatically applied when the train reaches a dead section, or the current is cut off. In the event of a breakdown or failure of supply three battery locomotives, which are kept in reserve at Mount Pleasant or at Terminal Stations, come into action.

These locomotives have drivers, of course, and their duty is to haul in any of the trains which have been brought to a standstill through failure of current or any other emergency.

Each of these locomotives is fitted with a battery of 163 lead acid cells with a capacity of 84 A.H. A fourth battery is kept in reserve.

During the latter stages of the work, before the Railway was in complete operation, these battery locomotives were kept in constant use while constructional and testing out work was in progress.

In addition to operating the three battery locomotives, lead cells are installed at each of the 8 stations for the automatic signalling and point working. At each station two batteries of 24 cells each are provided for working the motor driven points, track circuits and control circuits.

The operation of the trains is controlled by a traffic officer in a signal cabin with an electric lever frame, as in ordinary Railway practice. In this case, however, there are no drivers to whom he can give signals, so that when given a “right away” he actually puts the current on to the conductor rail and moves the train in the desired direction. These controls are fed by accumulators, which finally operate the coils of the power contactor which supplies the current to the rail. I mention this particular instance of the use of lead cells, not because there is anything remarkable in the size or number of the cells employed, but because it is interesting to find them performing a variety of essential functions in an undertaking embodying the most modern developments of mechanical and electrical engineering.

Industrial Trucks.

Under this heading may be comprised every kind of mechanically-propelled vehicle employed in Factories, Railway Station platforms, Docks, sheds, etc., etc., for the handling and transporting of goods. Internal combustion engines are inherently unsuitable for work of this character. Other reasons apart, the danger of fire and the contamination of the air would be sufficient to prohibit their use. It is a choice in this case between man transport and electric transport. Some form of self-contained vehicle is essential, as it must possess complete freedom of action and be capable of manœuvring in confined

spaces, so that trolley wire or live rail transmission is quite out of the question. By a process of elimination, therefore, we are left with the battery propelled vehicle as the only type of mechanical truck which meets the conditions. Just as the battery propelled street vehicle is the natural successor of the horse and cart, the battery truck is taking the place of the man with the barrow. Where labour is cheap, the material to be handled is of a suitable character, and the distances to be traversed are short, man transport, even to-day, can hold its own with mechanical transport. Such cases are, however, becoming increasingly rare. In countries like our own, where the cost of man power is increasing and manufacturing processes are on a continually growing scale involving the handling of larger units over greater distances at higher speed, the transport problem has become a very important and highly specialised one. In the majority of cases the use of battery trucks of one kind or another is the solution.

From a mechanical point of view the battery truck is the simplest and strongest industrial vehicle. It consists essentially of a simple four-wheel chassis, a battery, a motor and a controller. The operation of driving it involves merely steering, braking and manœuvring the controller lever. No skilled labour is required, and a few moments' instruction is sufficient for a man of ordinary intelligence. Probably the most familiar is the type used on station platforms with fixed flat top. Other types are provided with tipping bodies which can be driven and tipped by the driver alone, or with elevating platform tops, such that the truck can be driven under a stillage, and then by elevating the platform can be made to lift the load and transport it as required. A further model which is a development of the elevating platform truck, is the tier-lifting truck which will elevate its load to a height of 6 ft. 0 ins. This type of truck is of course useful for raising loads to deck levels or platforms or for stacking purposes.

In fact, the various adaptations to difficult handling problems are almost limitless. The tractor is another form of industrial truck. Under certain conditions the use of a truck purely as a hauling machine, with the load carried on one or more trailers, results in a considerable economy. While one trailer or trailers, as the case may be, are being loaded or unloaded the tractor is set at liberty to continue hauling. The use of electric industrial trucks in this country is in its infancy. Until four or five years ago it was scarcely more than a curiosity. Recently a considerable development has taken place, but we lag behind America in taking full advantage of the economies which can be effected by their use.

The usual industrial electric truck, dealing with loads of from 35 cwts. to 50 cwts., is equipped with a lead-acid battery of about 14 to 20 cells with a capacity of 200 to 350 A.H., depending on the size of the truck. The cells are of the Faure type in ebonite containers and are usually nested in wood crates holding from 6 to 8 cells in a crate. This enables them to be slipped into or

out of the truck with a minimum expenditure of time and labour. Thus one truck can be operated day and night, the battery being removed as soon as it becomes exhausted and a second fully charged battery put in its place.

Conclusion.

This rapid survey of some of the principal industrial applications of the lead acid cell will, I hope, afford an idea of the extent to which we are dependent upon it for certain essential services. It is a remarkable fact that with the solitary exception of the Iron-Nickel cell (and that only within rather narrow limits) no galvanic combination other than the lead couple has been discovered which will make a satisfactory accumulator. During the long period since Plante's original discovery numberless attempts have been made to find alternative combinations, but only one, the iron-nickel cell, has proved commercially practicable. This is the more remarkable, inasmuch as the number of theoretically possible galvanic couples which could act as accumulators are numerous. In view of the exhaustive investigations into this subject pursued over nearly 70 years, and their almost fruitless result, we may conclude that no revolutionary discovery is likely at this late date. The lead-acid cell, mechanically improved in details, but fundamentally unaltered, will in my opinion continue to function as our principal means of storing electrical energy for many years to come.

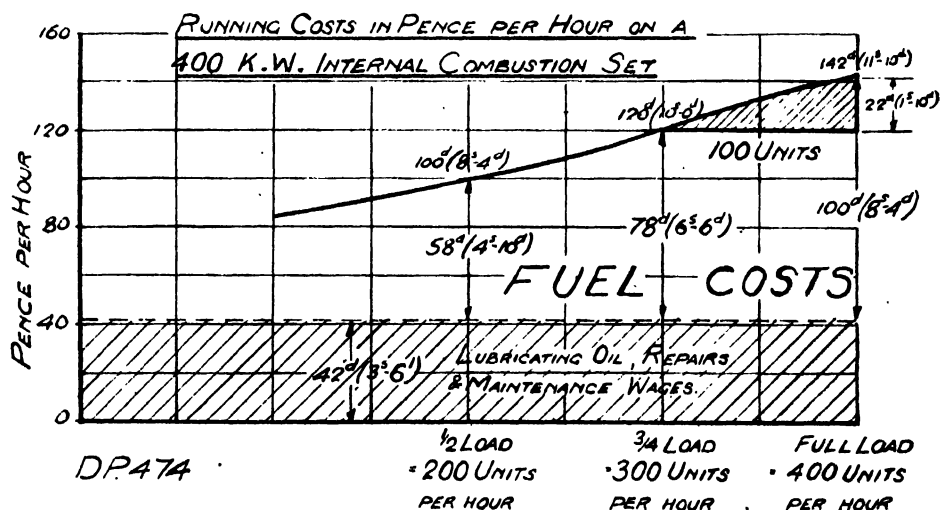


FIG. 8.—Fuel Costs Curve.

APPENDIX "A."

The use of batteries to improve the running plant load factor—

Fig. 8 is a chart showing the running costs on a 400 k.w. internal combustion set at all loads from a quarter load to full load. The fuel costs are shown as a

separate item, rising from 4s. 10d. at quarter load to 11s. 10d. at full load. These costs are based on the maker's guaranteed figures, with fuel oil at £4 10s. per ton. Wages, lubricating oil, repairs and maintenance, etc., are shown as a lump sum of 3s. 6d. per hour. This is a somewhat arbitrary figure, but it does not materially affect the conclusions. The small shaded portion of the chart illustrates the result of raising the load from three-quarters to full load, as, for instance, by putting a charge into a battery. The extra 100 units per hour thus obtained cost 1s. 10d. or .22d. per unit. Battery losses, assuming an efficiency of 75 per cent., will increase this to .28d. per unit. This compares with .4d. per unit (i.e., 300 units for 10s.) when running at three-quarter load. Thus it is an economy to load up sets which would have to be kept running in any case by putting a charge into a battery.

APPENDIX "B."

Some data relative to the operation of battery electric vehicles are given below :

TABLE I.

<i>Load capacity</i>	<i>Total weight with battery and load.</i>	<i>Capacity of battery at 80 volts.</i>
<i>Tons.</i>	<i>Tons.</i>	<i>A.H.</i>
1	3.5 (approx.)	130 (approx.)
2	5.5	200
2½	6.0	225
3	7.0	260
3½	8.0	300
4	8.75	330
5	10.0	375

N.B.—The capacity of the batteries in the above table is the minimum required to give 30 miles on one charge, with a consumption of 0.1 K.W.H. per gross ton-mile.

TABLE II.

<i>Load capacity.</i>	<i>Consumption per nett ton-mile (fully loaded).</i>
<i>Tons.</i>	<i>K.W.H.</i>
1	.5 (approx.)
2	.4 „
2½	.34 „
3	.33 „
3½	.326 „
4	.313 „
5	.286 „

N.B.—The consumption per nett ton-mile is based on battery input, so as to include battery losses, the battery efficiency being taken at 70 per cent.

Observed Figures for the operation of a 3½-ton Electric Lorry.

First Cost—Chassis with plain Lorry Body	..	..	£627
Battery	..	..	250.
Total..	..	..	£877

Standing Charges.

	£	s.	d.
Driver's Wages	149	18	0
Depreciation on chassis and body at 6½ per cent. ..	42	0	0
Interest on Capital	44	0	0
Licence	28	0	0
Insurance	16	0	0
(a) Total	£279	18	0

Running costs based on 7,000 miles per annum.

Battery renewals	£90
Electrical energy	50 (at 1½d. per unit)
Tyres	18
Maintenance	18
(b) Total	£176
(a) + (b) =	£455

Cost per vehicle mile 16d.

,, useful ton mile = 4.6d.

As an example of the operation of a privately owned fleet of 13 electric battery vehicles in the London area, the following data are interesting.

It was kindly supplied by Capt. Amor of the Mickleover Transport Company, who operates the fleet for the London Wholesale Dairies Company.

Nominal load (average)	2½ tons
Daily mileage	30-35 miles
Working days per annum	350
Annual mileage	10,000 to 11,000
Average age of vehicles	10 years

Each vehicle carries over half-a-million gallons of milk per annum.

The working costs are stated to be lower than with petrol vehicles on similar work.

DISCUSSION.

THE CHAIRMAN said that they had listened to a very interesting exposition, and he would like to offer his personal congratulations to Mr. Brown on his excellent paper. The paper afforded a concise survey of the history, the present practice, and the latest applications of secondary batteries. Such surveys were invaluable. They permitted one to view the subject in its true perspective. One was able to look back and see the steady advance which was made in time past, and forward to the possibilities of achieving still greater success. But in this case, when one looked forward what did one see? As Dr. Ferranti, in his recent Faraday Lecture, said, electricity supply was very considerably hampered by the want of a really good and cheap means of storing electricity. He (the present speaker) appreciated the fact that to solve this problem the scientists of many countries had spent much time, thought, and very considerable sums of money. On the other hand, one often heard engineers assert that the efficiency of apparatus of different types was so high that little incentive remained to stimulate ingenuity and originality in certain fields. Mr. Brown had given the efficiency of the lead-acid cell as 70-75

per cent., and of the nickel-iron alkali cell as 55-60 per cent. The lead-acid cell had certain drawbacks; it would not stand long without attention on open circuits, it was not very durable, and it was very costly in manufacture and upkeep. The alkali cell, on the other hand, was more expensive in first cost, and less efficient, and had other drawbacks. Therefore it seemed to him, in spite of the statement in the paper that no revolutionary changes in electrical storage development were to be expected, that there was ample scope, not only for the ingenuity and originality of research workers, but for positive enthusiasm.

He would not detain the audience with any discussion of the details of the paper because he saw many present who no doubt would like to contribute. A very old friend was present that evening in Col. Crompton. Col. Crompton this year celebrated his jubilee in the electricity industry. It was now fifty years since the world-famous firm of Crompton and Company was started, and here he was, still manifesting the keenest interest in every phase of electrical development.

COL. R. E. CROMPTON, C.B., R.E., who was received with applause, said that it was true, as the Chairman had stated, that it was nearly fifty years since he began in the electrical business, but it was forty-eight years since he began tackling the battery problem. He was an enthusiast then—he was called a mad enthusiast—for taking batteries up, but he still believed in batteries, and he was doing his very best to counteract the tendency of the young man of the present day to run in one groove and to imagine that there was only one form of distribution, namely, A.C. three-phase. Young men were apt to think there was nothing else, that it was impossible to conceive anything else, and it was very curious that this should be so. He believed the reason was that in the early days of batteries those concerned took the trouble to watch and understand them. He himself had sunk a great deal of money in making experimental cells, and if he had not been able to sell the rights to America at a very considerable amount he would have been very greatly out of pocket as a result of his experiments on batteries. If it had not been for the batteries, the very first installation, the lighting of the Law Courts, would have been a complete failure, but there was no breakdown in the Law Courts, and the result was so satisfactory that when he tackled the first big supply system in the world, which was the lighting of the Ring in Vienna, with all the theatres and public buildings around it, having a circuit of over a mile, he went in for batteries wholesale. From the batteries there, at the time of highest demand, about three-fourths of the load could be supplied. The success of the thing on a large scale tempted him to try the same in England, and he started with the company of which he was still chairman—he had been thirty years chairman—and which now held, he was proud to say, the record in London for lowest prices to the public and biggest dividends to the shareholders. If it had not been for his Vienna example being followed by all the companies, except Ferranti's, there would not have been any supply in London for many years, for at that time the development of supply by alternating currents was a very difficult thing, though it reflected tremendous credit on Ferranti, who did almost the whole thing by himself. But if they had had to face the stoppage of supply, such as did occur naturally with Ferranti's system, without any other resource to fall back upon, electrical development would have been put back for many years. On the contrary, the development went forward successfully, the companies he had mentioned paid dividends at an early stage, and the thing went ahead, so that Ferranti really had time to develop his system, and the splendid results were now seen all over the world.

The question was, were engineers right in putting battery supply out of the question? He claimed that they were not right. It might be that old people

like himself were ultra-conservative, but he held strongly that continuity of supply was of paramount importance. They were all aware what happened the other day when the Houses of Parliament were plunged into darkness. All the London companies suffered, his own company suffered, but because he had an enormous supply of batteries, out of his (nearly) one square mile of London, only about one-eighth of the square mile suffered total extinction. For the rest they managed to keep it up. The unfortunate batteries had a rough time of it, as the men switched in and switched out in the effort to get another source of supply, and the explosions reminded him of Flanders a few years ago; but it was a pleasure to see the men stand up to it; it was like a battle, and they won. There were twenty minutes only of low pressure, the unfortunate batteries could not do everything, but, by easing them, switching off part of them, and so on, they managed to pull through.

Even at his advanced age, therefore, he did not feel that they were wrong in adopting his system. But he had to confess that he was in a minority. He had shown to the best engineers in the land that in London the cost of this additional security would not be more than 0.3 or at most 0.4d. per unit, and he believed, that anybody would pay 0.4d. extra to have security in place of the increasing liability to extinction, which must occur in view of the gigantic scale on which the ring mains were worked. Everybody had heard of cases where, on large supplies being linked up together, terrible things had happened, a whole town being put out. He happened to be in close touch with Elihu Thomson, a very good adviser, and the latter had warned him as to what might happen when this gigantic grid system on which the whole country was going to depend came into being. He would like the author of the paper to know that he was doing his best to demonstrate that in the villages of rural England batteries might be the best form of electric supply. He did not know whether he would succeed in proving it from the financial point of view, but he thought he would. He had been rather a lucky man in prophesying happenings which had come out fairly correct. When, sixty-five years ago, he had prophesied mechanical transport, everyone thought he was a fool, but mechanical transport had pulled through! Similarly, when, fifty years ago, he started on the electrical business people thought it a little wild, but there was an electrical business to-day!

He wished to congratulate Mr. Brown on a valuable paper. It would be of use to him in the work he was trying to carry on. What Mr. Brown had said about Post Office tube locomotives reminded him that this type of unit was really worked out by an American engineer called Stuart and himself, was shown at his works at Chelmsford, and was then taken over by the Post Office twenty-four years ago, or something like that, and had now really got started at last! So much for the expedition of Government Departments! That was all he had to say, except to express his pleasure that the Society of Arts should have elicited so much valuable information which would be of use to all engaged in the electrical industry.

MR. LLEWELYN B. ATKINSON (Past President, Institution of Electrical Engineers) said that he knew next to nothing about batteries, but he hoped he might be allowed to say that in his view there was still great scope for some revolutionary invention. With all due regard to what had been said, the lead battery to the ordinary person possessed every disadvantage that any piece of apparatus could possess. If the car went wrong it was the battery; if the wireless would not work it was the accumulator. This was because the lead battery had one fatal defect—it would not stand being left alone when it was discharged. In the hands of ordinary people who did not know when it was charged or discharged this was a serious defect. In the winter months, when many people did not run their cars regularly and keep the batteries

charged, 50 per cent. of batteries got out of order and had to be replaced. The lead battery had been enormously improved within the last few years particularly, but still some revolutionary change was wanted. He added that that very morning he had been presiding at a meeting where everybody round the table had a wax candle because the service (in the Charing Cross district) was an A.C. supply which had "gone to sleep." Therefore, some system of storage was certainly needed, but he did not think the lead cell was the final answer.

MR. E. T. WILLIAMS (Admiralty) said that it was exceedingly difficult to follow a gentleman like Col. Crompton, whose machines, he remembered, figured in the very first textbooks he ever studied. He had had for a very long time a strong feeling that the battery had not been given a fair run. He wished to congratulate Mr. Brown on his paper, which was one of those surveys that enabled the whole question to be appreciated in its true perspective. Everything that made in that direction was to the good of electrical engineering, especially in that very much misunderstood business of storage. It was a very curious thing that of all the phases of electrical engineering that connected with storage had made least progress. As Dr. Ferranti had pointed out, if it were possible to store electricity economically, the advance in electrical operations and applications would be so great that no one could appreciate it to-day. Unquestionably a very great deal of research had been carried out with the object of discovering other types of batteries than the lead-acid battery, but, as the author had remarked, the only real outcome was the nickel-iron. But what he himself complained about was that so little attention had been paid until recent years to advancing the lead-acid battery in the way in which it should have been advanced.

Col. Crompton had spoken of Government departments. Well, there was one thing that Government departments had done, and this particularly applied to batteries for submarines and for the navy generally. The special requirements of the navy—considerable output for weight and space—had necessitated great attention by battery manufacturers to the Faure type battery, in regard to which remarkable advances had been made of recent years. This had been reflected in traction of all kinds, and he maintained that still further advances would be made in connection with the Faure type accumulator. Further improvements in connection with that type of cell would give it a very different aspect, both technically and commercially, from what it had to-day.

He could not quite agree with the lecturer that when one had these fluctuating loads one had better put in one's own plant and battery. He did not think it necessary to put in plant. Transforming apparatus could easily be installed, and the battery charged from the mains. In that case there was not the bother of running private plant, and all the advantages of public supply at low rates were secured. But it was a fact that in many instances, with fluctuating loads, it was a commercial proposition to install a battery because of the better terms that could be got from the power companies if they were given a good load factor. He had worked this out repeatedly, and had found it to be the case.

Those who had lived much abroad realised that, in new countries, small towns for many years to come would have to develop their independent electrical systems, and that in various parts of the Empire batteries would be essential. Therefore, he would urge all battery-makers to do propaganda work to impress consulting engineers with the really great importance of installing a battery with a small plant. There were many cases, both in this country and abroad, where schemes would have been an absolute failure financially if it had not been for the battery. They

would never have got to their present stage of progress if batteries had not been installed. If batteries had been in bad odour with engineers it was very largely because most of the batteries installed were very much too small and very much overloaded, and also because maintenance was very clumsily done.

With regard to traction, he could foresee several developments in electrical engineering. One combination was a comparatively small engine running continuously on a locomotive; when the locomotive was stationary the engine would charge the batteries, which at starting would assist the locomotive in getting up speed rapidly. With reference to industrial trucks, an attempt was made during the war to get electrical trucks in this country, but very few people knew what they were. Finally they had to be got from abroad.

He thought Mr. Brown was not quite fair to the alkali cell. It was certainly dearer, and had various disadvantages, but it was more or less fool-proof; it could be left uncharged for long periods, and he believed that, when one got to the stage of mass production, the alkali cell would be found to have a very real sphere of utility. The iron-nickel battery should not be too much disregarded, because in its own sphere it was likely to make great progress. We had in the battery an instrument of storage, admittedly with many faults and disabilities, but one which, had it been improved as it deserved to be improved in the past, would have made the position of the electrical industry different from what it was to-day. He begged that a real interest might be taken in this storage problem, that as much research as possible might be done on different types of battery, and then he believed that the effect on the future of electrical development would be very considerable.

MR. WORBY BEAUMONT said that to anyone dealing with the employment of power in works this question of the use of the battery as an equaliser was of very great importance. Recently, or for a few years, the development of the steam accumulator had been very much brought forward by Swedish, Norwegian, and German engineers, and at quite a large number of places where power in large quantities was used, steam accumulators had been installed so as to regulate the power output, and also to provide exactly the kind of service which the author had sketched in the early part of his paper.

He might remind the audience that Col. Crompton and himself were early experimenters in the making of secondary batteries of certain forms, some of which were in use even yet. This question of batteries on a very large scale was a matter of importance to anyone concerned in works or factories where the load varied very much, and where it was a question of relative expense of storing steam during part of the time or storing energy by means of the secondary battery. That, he thought, was one of the important questions referred to in the paper. Mr. Brown did not promise them very much in the way of economy, but he did mention things which showed that in certain circumstances, though the relative efficiency might not *per se*, be in favour of the battery, there were places where the battery might, after all, be the more economic appliance. He quite agreed with him in that.

With regard to road transport, it happened that, having had a great deal to do with means and methods of road transport, he was asked two years ago to prepare a small book on electrical vehicles, particularly industrial trucks, and so on, and he did so. For that reason he was specially interested in that part of the paper which dealt with these matters. Mr. Brown had remarked that the makers went for the heavy vehicles and neglected the lighter vehicles. It was a curious fact that the light electrical vehicle was not at first a success, for various reasons, but the heavy electrical vehicle began to go some way towards achieving success.

Gradually, however, in England as in America, the development of the lighter vehicle became a matter of careful study by commercial people. It had been found that, whereas the electrical vehicle was of small value to those who employed it, even in numbers, for long distances, it was economical in its use, provided the user had business enough to employ a number of them, and so could have command of a satisfactory charging installation. An Electrical Vehicle Committee had for some time been dealing with this matter, and had gradually secured the adhesion of quite a considerable number of those who were in an official position, and who were able to get charging stations established all over the country. There were now several hundreds of these stations where the commercial user might have the battery of his vehicles charged. But it still remained a fact that it was of no use to press upon users the value of one or two or three electrical vehicles; it could be pressed only when the business was large enough to make a large number of delivery vehicles of some kind essential to the conduct of the business. Complete success had attended the use of these vehicles by a few firms in London and a large number in America, but at the same time the electrical vehicle was of no importance except to those who had the commercial enterprise to study the question thoroughly. It had the advantage that when no power was being used it cost nothing, it was easily manipulated by almost anyone, and it might be left untended by the men engaged in delivering goods. On the other hand, the petrol vehicle could be taken to its garage late at night, the petrol turned off, and everything left just as though it were a wheelbarrow until the morning, a thing which could not be done with the electrical vehicle. All these things had to be remembered.

Progress had been achieved in one direction noted by the lecturer, namely, the electrical truck. In England the truck such as was to be seen at the railway stations had grown in use from originally a dozen or two to a great many hundreds, and in the development of that particular vehicle a great deal had been done. Certain traders had also set to work to build a light vehicle which should cost less to construct and meet their particular requirements. Mr. Brown stated that "two firms of electric vehicle builders at least are now producing a light one-ton delivery van which entirely meets requirements." He (the speaker) would rather say, "the particular requirements in view," because requirements were everywhere so different and needed such careful consideration. The manufacture of electric vehicles for trading purposes had thus grown to a very considerable industry in this country. At the time he wrote the book to which he had alluded—nearly four years ago—the thing was scarcely more than a curiosity, though trucks were actually being made by several people at that time, and the makers were struggling for some kind of recognition, which to-day they were getting from docks, railway people, men in charge of great warehouses, and so on, so that to-day it was as much as they could do to turn out these vehicles quickly enough.

Col. Crompton had very properly dealt with the most important aspects of the beginning of the electrical industry. It might have been modesty on Col. Crompton's part, but he had omitted to mention one thing, that in the old days Col. Crompton, the speaker, and the late Gerald Fitzgerald, were enabled to carry out experiments in the construction of batteries at the Crompton works, and as a result a great many things were discovered, in particular, certain forms which had been more or less used, and one of which, he still thought, might be brought into use. This was a form of plate the positive of which, instead of being formed simply in the Plante way, was prepared by a machine which, with a large number of quite small needles, punctured but not perforated the face of the plate, so that the plate presented an enormously increased surface that could be attacked by the electrolyte. These

and other experiments were made in the early days of batteries, and were very interesting to look back upon.

MR. E. NEW regretted that the lecturer had not referred to one matter which was of great interest, namely, that of standardisation. There were great difficulties in the way of standardisation, but the Post Office, to which the lecturer had referred, had done very valuable work in connection with standardising the batteries which the department employed, and the speaker thought it should be put on record that that work had been done, and, further, that there was a very strong committee of the British Engineering Standards Association now sitting on which all the Government departments were represented, and there were great hopes that the result would be a standardisation which would do away with the existing chaotic practice of manufacturing batteries of a great number of different types and dimensions.

MR. E. C. MCKINNON, M.I.E.E., pointed out that in one respect the lecturer had not made the best possible case for the lead-acid cell. The lecturer stated that "at the present time a reasonable expectation of life for a submarine cell is about five years." Whilst this might be correct for the ordinary flat pasted type plates, lead-acid cells included the Exide-Ironclad type, the life of which, in submarine service, had already been proved conclusively to be at least eight years. Many of these cells were still in service after ten years' submarine service. Again, in comparing the life of the lead-acid cell with the alkali or iron-nickel cell the lecturer had quoted a life of three years for the former as against six to eight years for the latter. He had pointed out, however, that two makers gave a three years' guarantee for the lead-acid cell, and certainly in the case of the manufacturer of the Exide-Ironclad cell this guarantee was on a very conservative basis, and under road transport conditions the life should be regarded as from three to five years.

MR. E. T. WILLIAMS, with reference to the remarks of the last speaker, said that it was not any relatively low efficiency of the battery which was the most serious obstacle; it was the shortness of life.

MR. WORBY BEAUMONT said he wished to add a reference to what Mr. Atkinson had said about batteries used in motor-cars, either for starting or for giving light on cars. Mr. Atkinson had spoken of many difficulties with and imperfections of the battery, but it might be that the battery maker would reply by pointing out that these batteries ought not to be in the hands of people who did not thoroughly understand them and take the pains to attend to their requirements. If they were attended to and their requirements were appreciated, most batteries that were supplied were really quite satisfactory for automobile work.

MR. J. N. SOUTHERN said that Mr. Brown had given some very interesting facts with regard to the various uses to which accumulators were put. He had also given a little—though very little—technical information. But he felt that anyone not closely connected with the trade would still feel that a storage battery was a box of mysteries. In dealing with the uses of storage batteries in central power stations, there were circumstances which Mr. Brown had not mentioned. Storage batteries were used for switchboard lighting and for station lighting. The speaker was having a conversation with an engineer the other day, who told him that he had changed his system from D.C. to A.C., but he had taken the very wise precaution

of having 75 per cent. of his station lighting and the whole of his switchboard lighting on an independent low-voltage supply ; for this purpose he had installed the storage battery. It was very regrettable that power engineers did not invariably install local storage batteries. It was time the public realised that no penalties at present existed for a breakdown in the continuity of supply. There was an authority in the north of England which on its housing estate had made electricity widely available, so that electricity provided the only means of lighting, heating, and cooking on that estate. But in the event of a breakdown of supply the consequences were all the more serious, and on a cold day the only way in which the tenants could get warmth would be to go to bed. Such a breakdown, indeed, had occurred, but if only a storage battery had been installed, preferably at the consumers' end, a different tale might have been told.

Again, take an everyday scene in a hospital. An operation was taking place, and upon the skill and expedition of the surgeons the life of the patient depended. Suppose the light failed for a lengthy period, what would happen ? The patient's life might be sacrificed. If a storage battery were installed then the work of mercy could continue. He also thought that storage batteries should have a place in all prisons and asylums.

He agreed with the lecturer that, instead of blaming the trams for the congestion of the roads, horse-traffic should be withdrawn from the central streets. The speed of the most rapid motor-car was governed by that of the slowest horse-drawn lorry. Not only should horse traffic be withdrawn, but petrol lorries should be eliminated from the centre of big cities, and more facilities should be given in the way of charging stations. Then there would be not only ideal homes but ideal streets " worthy for heroes " to work and walk in.

MR. HAROLD G. BROWN, in replying on the discussion, said that he did not think there was anything he could add to Col. Crompton's remarks. The case for the battery could not have been put with more force and emphasis. Col. Crompton's services to the battery industry deserved the gratitude of everybody connected with it.

Mr. Atkinson had painted a rather gloomy picture of the lead-acid cell. He pointed out that if a car would not start the trouble was usually attributed to the battery. That might be the case in most instances, but at the same time he had come across one or two people who did not know where the battery on the car was ! They seemed to have forgotten the existence of the battery, and when it was dug out probably no acid was found in it. Then, again, a similar trouble arose over wireless cells sent to some local man to charge. He had known cases where the man had simply tipped the acid out, put in strong acid, and sent back the battery as fully charged.

Mr. Williams had mentioned the case of a private consumer putting in his own battery, but in his paper he (the speaker) had not meant exactly that the private consumer should put in his own plant—that is to say, the actual generating plant—but a battery. It was not every power company that would allow a private user to charge his battery on power terms. Companies often would not allow current to be used for charging a battery, at least at power rates. There was room, he thought, for improvement in that direction.

Mr. Beaumont had referred to the steam accumulator ; the speaker was afraid that that was outside his knowledge. He had also mentioned the difficulty of charging electrical vehicles unless there was a fleet of reasonable size. Of course that was a big difficulty. It might be quite a profitable thing to run a couple of

vehicles, but when it meant that a small charging plant had to be installed the proposition was rather knocked out on the score of price. It would be a good thing if charging stations could be installed throughout the country, as this would lead to the greater use of electrical vehicles.

Mr. McKinnon had referred to the life of cells. In the paper he had mentioned three years for the lead-acid cell and from six to eight years for the iron-nickel. His figures were based on the use of cells for electric lorries for road transport, and he did not think the comparison was an altogether unfair one. If the conditions were such that the alkali battery would last from six to eight years, probably it would be difficult to get more than three years out of the lead cell. The better method of estimating life was by cycles rather than years, and, indeed, it was rather misleading to mention years at all in connection with batteries on traction work. At the same time, three years was the term of guarantee which could be obtained from two well-known makers, and, when basing the costs, it was naturally upon the guarantee that one based them.

Mr. Southern had suggested that the paper had not given much technical information. But the paper was not intended to deal with the technical aspects of the lead cell. It was just a survey of the position of the industry as it stood to-day. Had he attempted to deal with the technical aspects the paper would have run to undue length.

THE CHAIRMAN said that the Society had had an excellent paper and an interesting discussion, and he proposed a vote of thanks to the author.

The vote of thanks having been carried unanimously, the proceedings terminated.

MR. T. DOWNES (London and North Eastern Railway) writes :

The paper is certainly very interesting and instructive and, having had considerable experience with accumulator cells for railway working since the early days of electric lighting and various other purposes, I am particularly interested in Mr. Brown's remarks in relation thereto.

His reference to the uses of accumulators for electric signalling, particularly in connection with the remote operation of points, is opportune, and as a pioneer working in this direction, I can confirm that the application of accumulator cells for this purpose will, in my opinion, be an economic proposition.

From working experience I am not yet in a position to state definitely the standard sizes or the trickle charge output, but this would appear to be in the neighbourhood of about 100 milliamperes and the requirements could most conveniently be met by being able to store in a dry condition fully charged accumulators which could be brought into use at remote locations by the addition of electrolyte on the spot.

NOTES ON BOOKS.

PRACTICAL PHYSICS. By T. G. Bedford. With Diagrams. London : Longmans, Green and Co., Ltd. 10s. 6d. net.

Mr. Bedford, acting as demonstrator in the Cavendish laboratory at Cambridge, has realised how important it is for the pupil to become his own teacher, by dealing with objects or things as we find them ; thus from objects and laws obtaining

a first-hand instruction. Mr. Bedford's course is for the most part quantitative, and, as far as practicable, specially expensive apparatus is excluded. The whole range of experimental physics, as ordinarily understood, is well covered : mechanics, heat, light, sound, electricity, magnetism. One example will suffice.

On p. 98, section 119 illustrates by diagram and words the nature of viscosity in liquid, as shown when two planes slide on each other with a stratum of liquid between them. Next is an easy mathematical development, and on the following page the mind is led by diagram and practical test to consider the passage of a cylinder or column of water through a fine-bore tube. Finally, on p. 100, we find sketched (Fig. 57) the apparatus for quantitatively determining the viscosity of water, this being a vertical small-bore glass tube passing upwards into a tubular cistern of glass, in which the water is kept at constant level by means of a Mariotte's bottle. The rate of flow, or drip is the primary interfunctional with the viscosity ; but for a realisation of the many conditions or issues affecting the result we must refer the student to the book itself ; a volume of practical fact, and of a kind much wanted in our present period of extreme speculation and many hypotheses.

A PRACTICAL TREATISE ON OUTBREAKS OF FIRE. By Sidney G. Gamble. With Frontispiece Plates and 348 Illustrations in the text. London : Charles Griffin and Co., Ltd. 30s. net.

In 544 + XII closely-printed large-octavo pages, the author, who is so well known as a first-hand authority on his subject, gives us a pleasantly readable, fully illustrated volume, which is encyclopædic in its completeness and thoroughness.

The first 17 pages of the text are occupied by historical notes commencing with the Deluge and ending with St. Barbe, the patron saint of firemen in France, and among the illustrations to this section may be mentioned the Curfew or *Couvre-Feu* shown on p. 3 : a large decorated copper extinguisher for the domestic fire. The historical element, however, runs usefully throughout the book as regards the object under consideration ; for example, the illustrations on pp. 406-407, showing the costumes of those engaged in fire extinguishing from Roman times onwards ; while on 349 we have sketches and descriptions of early or ancient forms of the *sipho* or extinguishing syringe.

Somewhat over 30 pages (18 to 50) are very usefully devoted to a delightfully lucid, but somewhat unfettered or popular study of " Air, Water and Fire " from the chemical and physical points of view.

In the same pleasant, but carefully considered, manner the author brings before his readers first history ; and then present usage : but precautions, though cropping out at all points, are specially assembled and classified in Chapter II, *Dangerous Trades*, pp. 117-198, and summarised in the list of " Do Nots," pp. 499-502. Apart from its use in training firemen, this volume should be of great value to manufacturers, storekeepers and householders.

THE ECONOMIC REVOLUTION IN BRITISH WEST AFRICA. By Allan McPhee. One of the Monographs by writers connected with the London School of Economics and Political Science. London : George Routledge and Sons, Ltd. 12s. 6d. net.

Chapter VIII, " Health," gives us the basic motive of this work. For century after century the three hundred miles or so of coast-line, shown on the map opposite p. xii (Gold Coast) ; also the longer and more irregular coast (Nigeria), seen by turning over, have been almost without economic development in any real sense

of the term ; the first few pages of Chapter VIII giving a series of vivid pictures of the insanitary condition before those changes which came with the enlightenment of the second half of the nineteenth century ; abundant reference to authorities being given in the foot notes, as also to parallels, governing principles, and illustrative historical events. The triumph of man over the various insect foes runs as a strain through the volume ; the climax being the author's Medical Revolution, which followed an identification of " the actual species of mosquito " concerned in transmitting the so-called malarial infection (p. 284). This great service we owe to Major Ronald Ross (afterwards Sir Ronald), who published his results from 1899-1902. The author mentions prior but less definite work in a similar direction, but we find no mention of the far back and more or less erratic work of Dr. Katerfelto, who is stated on p. 510, Vol. I, Chambers' Book of Days, Ed. of 1863, to have " practised on the people of London in the influenza of 1782 " : the authority being a pamphlet published in 1805. On the next page of the Book of Days we have quotations from a *Morning Post* advertisement of 1782 which seems to show that about midsummer, 1782, Katerfelto gave daily exhibitions by the then novel solar microscope ; one object exhibited being " insects which caused the late influenza." It may be conjectured that Katerfelto's influenza-causing insect is the blood-sucking midge (*Culicoides pulicaris* L.), the tiny gnat referred to in some detail on pp. 650-651 of *Nature*, April 21st, 1928.

The author's Medical Revolution being satisfactorily consummated, the Industrial (or Economic) Revolution, guided by that dynamic factor of British Colonisation set forth on p. 274 as " education of native rulers in the principles of just and civilised government," follows almost automatically. The detailed story, as told by Dr. McPhee in XII + 322 pages of scholarly writing, is good reading for young or old.

STORIES IN STONE. By Willis T. Lee. London : Chapman and Hall, Ltd. 15s. net.

In somewhat over 200 pages of words, aided by 32 inset plate illustrations, Mr. Lee, the geologist of the United States Survey, makes his readers acquainted with the stone marvels of Western America, but he also includes many teachings and views of world interest, such as the rise of animals from water to land, p. 61 ; and here he tells us of huge insects, as, for example, cockroaches four inches long and dragonflies with a wing spread of over two feet, p. 61 ; casts or remains being found in the carboniferous strata. Such unpleasantly large insects as these are not the only animal horrors to which Mr. Lee introduces us, happily only in dead stone ; Plate XXXII showing us Mr. C. R. Knight's restoration of *Tyrannosaurus Rex*, a dino-saur of unfriendly aspect some 40 feet high with jaws five feet long and sharp teeth suited for tearing flesh. On pp. 137-138 we are shown a contrasting friendly little animal, his picture being drawn by Charlotte P. Stetson in words, and we may quote one of the stanzas, which probably sings a sound palaeontology :—

" Said the little Eo-hippus,
 ' I am going to be a horse !
 And on my middle finger nails
 To run my earthly course !
 I'm going to have a flowing tail !
 I'm going to have a mane !
 I'm going to stand fourteen hands high
 On the psychozoic plain ! ' "

The author, whose death is mentioned on p. xii as having taken place in 1926, before the book was put in type, leads us by words and by pictures through the regions where changing natural conditions have given us the fantastically wild features in primitive rock, intermediate formations in rock, and also indurated deposits which are features in the extensive districts of North America now set apart as "National Parks" or "National Monuments." Sandstone deposits in gaps of the older rocks, when cut by flowing water, have given us the surprising natural bridges of Utah, which the author tells us were "first made known to the general public in 1904;" p. 65. Of the four natural bridges depicted in the inset plates, the Carolina Bridge (p. xviii) is the most ruggedly massive and least shapely, but the three others are so symmetrical that each almost suggests a definite geometric curve; a catenary in the case of the Rainbow Bridge (Pt. XXVI) with its span of 278 feet with clear height of 309 feet. The reader may study for himself the enormous natural arches shown by Plate XVII and Plate XIX.

If the book contained nothing more than we have mentioned, we could recommend it as an instructive and charming reading book or library volume; it however contains much more, as the reader will discover by a glance through the index or over the plates.

RAFFLES DAVISON: A RECORD OF HIS LIFE AND WORK. London B. I Batsford, Ltd. 21s.

Mr. Raffles Davison is an architectural draughtsman of acknowledged competence. In the present book, following on a number of forewords by such distinguished men as Sir Aston Webb and Sir Reginald Blomfield, there are republished an essay by Mr. Davison and a considerable selection of his drawings—mainly of houses, institutions, churches, with some showing architectural detail, and others of landscapes, views in village streets, etc. These drawings are accurate and in an agreeable way effective. Mr. Davison's technique is sure, and, better than any photograph, he can with a few lines suggest the aesthetic qualities of a font or a porch.

But of course it is not the same thing to suggest the aesthetic qualities of the model as to communicate aesthetic qualities to the representation. Mr. Davison's function at one time was to give practising architects a clear pictorial sketch of what their designs would look like when completed. It is therefore not hard to understand why a certain insistence on realistic accuracy is both the strength and the weakness of his work. His art may scarcely be said ever to take wings to soar up from the earth, yet it is not so earthbound as to lack charm. The view of Hanley Castle Church on a summer afternoon (Plate XVI), with its sunshine and shadow, almost makes one hear the humming of bees. It is surprising to find that the drawing of Le Sueur's Charles I, should have so peculiarly missed the rhythm, the concentration and the dash of what is perhaps the best or the second-best of our London statues.

Mr. Davison's genial paper on the art of drawing deals partly with the value of draughtsmanship to architects, partly with the art itself, independent of utilitarian considerations. In answer to the argument that architects may be distracted from their strict professional duties by the allurements of drawing, he makes the very good reply that at least they may be saved by this means from setting up some very ugly buildings. Not only drawing, but also modelling should more often be resorted to as an aid to working out architectural designs. But, as the writer points out, the art of architecture is not "a leisurely one, as it ought to be." It

is obvious that anyone with original ideas who wants to break away from tradition, or even carry it on to a further stage, would gain much by doing for himself what Mr. Davison has so often done for others. Traditional forms can be studied in many places in England and Europe; the innovator must have drawings or models.

The author is on treacherous ground when he writes that in his opinion the value of art "lies in the inspiration and enthusiasm which it may create." He speaks with praise of the enthusiasm which Ruskin created. It also appears that Ruskin once told Mr. Davison that he should never draw while in a place "surrounded by the most bestially degraded forms of human industry." With this irrelevant advice Mr. Davison happily would have nothing to do. But art has no more to gain from "enthusiasm" than it has to lose from "degraded forms of human industry." The three things are on three different planes. Factory chimneys belching smoke are deplorable, certainly; but "degraded forms," transformed by art, may become aesthetically beautiful forms. As for enthusiasm, it is surely a mood. Art is a subtle human method of eliciting a kind of order from chaos. This is value enough.

P.B.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, MAY 21..Architects, Royal Institute of British,
9, Conduit Street, W. 8 p.m. Mr. H. P. Adams,
"English Hospital Planning."

Geographical Society, at the Æolian Hall, 135, New
Bond Street, W. 8.30 p.m. Dr. J. C. Shattuck,
"A Journey in Liberia and the Eastern Congo."

Wales, Council for the Preservation of Rural, at the
ROYAL SOCIETY OF ARTS, Adelphi, W.C. 3 p.m.

University of London, at King's College, Strand, W.C.
5.30 p.m. The Rev. Dr. R. S. Franks, "The Meta-
physical Justification of Religious Experience."
(Lecture III.)

5.30 p.m. Mr. H. Wickham Steed, "The Prelude
to the War." (Lecture IV.)

At the London School of Economics, Houghton
Street, Aldwych, W.C. 5 p.m. Prof. Dr. Ludwig V.
Mises, "Economic Theory and the Social Problem."
(Lecture I.)

At University College, Gower Street, W.C. 5 p.m.
Prof. Dr. G. Dawes Hicks, "Ruskin's Theory of Art."
(Lecture III.)

TUESDAY, MAY 22..Anthropological Institute, at 52,
Upper Bedford Place, W.C. 8.30 p.m. Prof. J. L.
Myres, "Ancient Greek Physical Types."

Illuminating Engineering Society, at the Home Office
Museum, Horseferry Road, S.W. 6 p.m. Annual
Meeting. Discussion on "The Illuminating Engineer-
ing Movement at Home and Abroad."

University of London, at Guy's Hospital Medical
School, St. Thomas's Street, S.E. 5 p.m. Prof.
J. B. Leathes, "The Human Kidney and the Physio-
logical Study of Human Urine." (Lecture III.)

At King's College, Strand, W.C. 5.30 p.m. Señor
Don F. J. Sanchez Canton, "Drawings and Etchings
of Goya" (in Spanish).

At University College, Gower Street, W.C. 5 p.m.
Prof. Laurence J. Henderson, "Blood, A Study in
General Physiology." (Lecture IV.)

WEDNESDAY, MAY 23..British Academy, Burlington
House, W. 5.15 p.m. Dr. W. W. Greg, "Principles
of Emendation in Shakespeare."

Geological Society, Burlington House, W. 5.30 p.m.
Prof. Dr. P. G. H. Boswell, "The Geological Features
of the New Mersey Tunnel."

University of London, at Guy's Hospital Medical

School, St. Thomas's Street, S.E. 5 p.m. Prof.
J. B. Leathes, "The Human Kidney and the Physio-
logical Study of Human Urine." (Lecture IV.)
At the Institute of Historical Research, Malet Street,
W.C. 5.30 p.m. Dr. Dragutin Subotic, "Serbo-
Croat Literature of the 15-18th Centuries with reference
to Italian Influence." (Lecture II.)

At the London School of Economics, Houghton
Street, Aldwych, W.C. 5 p.m. Prof. Dr. Ludwig v.
Mises, "Economic Theory and the Social Problem."
(Lecture II.)

5 p.m. Dr. Hubert Hall, "Some common factors in
the Economic and Social Development of England
in Mediaeval and post-mediaeval Times." (Lecture IV.)

THURSDAY, MAY 24..Aeronautical Society, at the ROYAL
SOCIETY OF ARTS, Adelphi, W.C. 6.30 p.m.

University of London, at the Imperial College of Science,
Royal School of Mines, South Kensington, S.W.
5.30 p.m. Dr. Edward M. Kindle, "Types of Sedi-
mentation on the Atlantic Coast of N. America."
(Lecture I.)

At King's College, Strand, W.C. 5.30 p.m. Señor
Don F. J. Sanchez Canton, "Goya's Place in the
History of Painting" (in Spanish).
5.30 p.m. Mr. S. A. Handford, "Ancient Ruses of
War."

At University College, Gower Street, W.C. 5 p.m.
Prof. Laurence J. Henderson, "Blood, a Study in
General Physiology." (Lecture V.)
5.30 p.m. Major George Haven Putnam, "Abraham
Lincoln."

FRIDAY, MAY 25..Physical Society, at the Imperial College
of Science, South Kensington, S.W. 5 p.m.

Royal Institution, 21, Albemarle Street, W. 9 p.m.
Mr. A. C. Egerton, "Engine Knock and Related
Problems."

University of London, at the Imperial College of Science
and Technology, South Kensington, S.W. 5.30 p.m.
Sir William J. Pope, "Recent Progress in Stereo-
chemistry." (Lecture II.)

At the Institute of Historical Research, Malet Street,
W.C. 5.30 p.m. Dr. Julian Krzyzanowski, "Polish
Culture in the Middle Ages." (Lecture III.)

At King's College, Strand, W.C. 5.30 p.m. Mr.
R. G. Collingwood, "Roman Britain and Recent
Excavations." (Lecture II.)

At the London School of Economics, Houghton Street,
Aldwych, W.C. 5 p.m. Mr. Philip Noel Baker,
"The Covenant and Before."

At University College, Gower Street, W.C. 5 p.m.
Prof. Laurence J. Henderson, "Blood, a Study in
General Physiology." (Lecture VI.)

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FRIDAY, MAY 25th, 1928.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.(2.)

NOTICES.

COUNCIL.

A meeting of the Council was held on Monday, May 14th. Present :— Sir Philip Magnus, Bt., in the Chair ; Sir Charles H. Armstrong ; Lord Askwith, K.C.B., K.C., D.C.L. ; Mr. Llewelyn B. Atkinson, M.I.F.E. ; Rt. Hon. George N. Barnes, C.H. ; Sir Charles Stuart Bayley, G.C.I.E., K.C.S.I. ; Captain Sir Arthur Clarke, K.B.E. ; Sir Dugald Clerk, K.B.E., D.Sc., F.R.S. ; Mr. Peter MacIntyre Evans, M.A., LL.D. ; Sir Alexander Gibb, G.B.E., C.B. ; Sir Robert Abbott Hadfield, Bt., D.Sc., F.R.S. ; Rear-Admiral James de Courcy Hamilton, M.V.O. ; Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S. ; Sir Herbert Jackson, K.B.E., F.R.S. ; Major Sir Humphrey Leggett, R.E., D.S.O. ; Sir Reginald A. Mant, K.C.I.E., C.S.I. ; Hon. Sir Charles A. Parsons, O.M., K.C.B., LL.D., D.Sc., F.R.S. ; Sir Richard Redmayne, K.C.B. ; Sir George Sutton, Bt. ; Mr. Alan A. Campbell Swinton, F.R.S. ; Mr. Carmichael Thomas ; Professor John Millar Thomson, F.R.S. ; Lt.-Col. Sir Arnold T. Wilson, K.C.I.E., C.S.I., C.M.G., D.S.O. ; and Sir Alfred Yarrow, Bt., F.R.S., with Mr. G. K. Menzies (Secretary), and Mr. W. Perry (Assistant Secretary).

The question of the award of the Albert Medal for 1928 was further considered and names were selected for submission to H.R.H. the President.

The preparation of the balloting list for the new Council was completed.

It was reported that the number of entries for the May examinations for 1928 was 43,403, an increase of 3,741 on last year.

The recommendation of the Preservation of Ancient Cottages Executive Committee that an Annual Meeting of subscribers be held at an early date, was approved.

A Committee was appointed for the purpose of adjudicating the award of the Society's silver medals for papers read during the session 1927-28.

The following candidates were duly elected Fellows of the Society :—

Cockburn, Sir John Alexander, K.C.M.G., M.D., London.
 Cohen, Isaac Michael, R.P., London.
 Elliot, Spencer Graham, M.D., C.M., London.
 Herdman-Smith, Robert, Wareham, Dorset.
 Higgins, Frank Wilfred, London.
 Huke, Reginald William, St. Margarets-on-Thames, Middlesex.
 Kynaston, B. H. J., West Bridgford, Notts.
 Littlejohns, John, R.B.A., London.
 Macy, Ralph G., New York City, U.S.A.
 Madley, Alfred Edmund Guy, Westmount, Canada.
 Markande, Pandit Din Daval, Srinagar, Kashmir, India.
 Mullick, Prem Chand, Allahabad, U.P., India.
 Ogilvy, Miss E. B. Tapply, London.
 Platt, John, M.Inst.C.E., New York City, U.S.A.
 Platts, Captain Cyril Stanley, Kingston Hill, Surrey.
 Ridgway, Ellis Branson, Coatesville, Pa., U.S.A.
 Slade, Tom, London.
 Verity, George M., Middletown, Ohio, U.S.A.
 Webster, George Roland Harding, Cambridge.
 Wilden-Hart, Professor Bernard John, M.A., London.

A quantity of financial and formal business was transacted.

TWENTY-SECOND ORDINARY MEETING.

WEDNESDAY, MAY 16th, 1928. ALAN A. CAMPBELL SWINTON, ESQ., F.R.S., a Vice-President of the Society, in the Chair.

A paper entitled " Modern Motor Car Design " was read by MR. W. WORBY BEAUMONT, M.Inst.C.E. The paper and discussion will be published in the *Journal* dated July 6th.

DOMINIONS AND COLONIES SECTION.

TUESDAY, MAY 22nd, 1928. LIEUT.-COL. THE RIGHT HON. SIR MATTHEW NATHAN, P.C., G.C.M.G., LL.D., in the Chair.

A paper on " The Gambia Colony and Protectorate " was read by CAPTAIN SIR CECIL ARMITAGE, K.B.E., C.M.G., D.S.O.

The paper and discussion will be published in the *Journal* dated July 13th.

BINDING COVERS FOR JOURNALS.

For the convenience of Fellows and others wishing to bind their annual volumes of the *Journal*, cloth covers can be supplied, post free, for 2s. each, on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.

SEVENTEENTH ORDINARY MEETING.

WEDNESDAY, 21ST MARCH, 1928.

COLONEL SIR HENRY LYONS, D.Sc., F.R.S., Director of the Science Museum, South Kensington, in the Chair.

The following paper was read :—

THE MODERN TYPEWRITER AND ITS PROBABLE FUTURE DEVELOPMENT.

By LIEUT.-COMMANDER R. T. GOULD, R.N. (Retd.).

Some thirty-odd years ago, in 1894, two Cantor lectures on "Typewriting Machines" were read before this Society by Mr. Henry C. Jenkins, A.M.I.C.E. In these lectures he gave a very clear and concise account of the evolution of the typewriter from the date of the first recorded patent upon the subject—that of Henry Mill, taken out in this country in the year 1714—up to the time at which his lectures were delivered. It is my object to-night to take up the story of the typewriter where he left it off, and to give you, first, a short account of what has since been done towards the improvement of typewriters in general; and, secondly, a few criticisms and suggestions upon the subject of what further developments we may reasonably expect.

At the outset, there is one point which I should like to make quite clear. Mr. Jenkins was a trained engineer, and part-designer of an exceedingly ingenious typewriter—the "Waverley." On the other hand, I am not an engineer, nor have I ever had anything to do with the designing of typewriters or with the commercial side of the typewriter trade; and while I have done a good deal of typing on various makes of machine I have no claim to be considered an expert typist—my typing is of the "peck and hunt" variety, in which great use is made of the two first fingers, to the comparative exclusion of the remainder. It necessarily follows that this paper has no claim to be regarded as authoritative, or as being anything more than a synopsis of a layman's personal opinions—opinions not always, I fear, so well-informed as they might be.

I shall only deal very briefly with events before 1894. As I remarked above, the earliest patent for a typewriter was taken out in 1714. But this was an isolated portent. Nothing whatever is known of the mechanism of Mill's machine—in those days patents were very loosely and vaguely drawn—and no example of it has survived. It is even doubtful whether the machine was ever constructed, since although the patent recounts that Mill has " . . . by his great study, paines and expence, lately invented *and brought to perfection* an artificial machine . . . for the impressing or transcribing of letters . . . "

such expressions as "brought to perfection" are common form in the early patents, and generally bear no more relation to the actual fact than the "force and arms," and the "peace of our Lord the King, his Crown and Dignity" of a writ for trespass.

After Mill, the subject of mechanical writing seems to have slumbered, in an almost unaccountable fashion, for over a century. Machines of which but little is known were sporadically produced from time to time—by Von Knaus and Reippert in Austria in 1760, by Jaquet, of Neuenberg, and the Frenchman Pingeron in 1780, by Turri, of Castelnovo, in 1808, and by Conti, of Cilavegna, in 1823, but none of these appears to have been of much practical value and they were probably as much hand-printing-machines as typewriters. But the Burt "Typographer," or "Family Letter-Press," invented by William Austin Burt, of Detroit, in 1829, was a workable machine, and produced several very creditable pieces of writing. Its operation however was slow and, probably owing to this cause, it met with no commercial success. It has often been pointed out that no typewriter could hope to rival the pen—and, therefore, no typist could survive in competition with writing clerks trained to produce "copper-plate" handwriting at sixty words a minute—unless it could provide not only a clearer method of writing, but also a faster one. Burt's machine was the first example of the "index machine," of which I shall have a little to say later. A replica of it (the original was burnt in the fire at the U.S. Patent Office in 1836) and specimens of its work can be seen in the Science Museum, South Kensington. In this connection, I should like to express my gratitude to Sir Henry Lyons, and to his officials, for the great assistance which I have received from them at all times when studying the subject of the typewriter; and I should like, at the same time, to express my thanks also to the various typewriter firms who have assisted me with information and with the loan of machines for exhibition to you to-night.

After Burt came many other inventors, of whose ingenious labours fairly full accounts are available from several sources. Most of them produced machines fully capable of good mechanical writing, but still handicapped by their slowness of operation. One of these, however, the Hansen "Schriebkugel," or "Writing Ball" of 1871, obtained quite a footing on the Continent, and was still employed in a few offices there not so many years ago.

But the Hansen, although a clever machine, was radically defective in design (although a machine of very similar arrangement, the Schade, was put on the market in Germany much later, in 1896), and the real ancestor of all commercial typewriters must be looked for on the other side of the Atlantic. In 1872 the famous Remington Armoury at Ilion, U.S.A., began the manufacture, on a commercial scale, of the Sholes-Densmore typewriter—an enterprise which, under the style of the Remington Typewriter Company, has been continued ever since. For the first time it became possible to purchase,

at a reasonable price, a mechanical writing-machine which could beat the pen both for speed and legibility, and which, in addition, possessed the power of manifolding. The typewriter still had a hard struggle for recognition in front of it—but, for the first time, success was in sight.

For some years the Remington typewriter, as it came to be called, stood alone—so much so that the Remington Company at first styled it simply "The Typewriter." Like all innovations, it met with a chilly reception—particularly, and naturally, in this country. It was much harder to sell the machine than to make it, and it was harder still to find operators for it. When this had been done, typewritten correspondence had still to surmount a large barrier of stubborn popular prejudice—a prejudice which, so far as relates to the use of a typewriter for private correspondence, still in some measure exists. It is, by the way, amusing to note that C. L. Sholes, the inventor of the first Remington machine, not only used it for every scrap of his correspondence, but type-wrote his signature—a proceeding which even at the present day, would be regarded as unusual, and, in the case of an official document, probably illegal (although I believe that in certain cases the use of a rubber-stamped signature is legitimate).

Many tales are told of the indignation felt by recipients of their first type-written communication. A Kentucky mountaineer returned one such to its author, with the terse marginal comment, "You don't need to print no letters for me. I kin read writing." I should mention that the Model 1 Remington wrote capital letters only. Less blunt, but equally poignant, was the dignified rejoinder of an aggrieved district agent to one J. P. Johns, a Texan banker, in the following terms:—

" . . . I realize, Mr. Johns, that I do not possess the education which you have. However, until your last letter I have always been able to read the writing. I do not think it was necessary then, nor will be in the future, to have your letters to me taken to the printers, and set up like a handbill. I will be able to read your writing, and am deeply chagrined to think you thought such a course necessary. . . ."

On the other hand, some of the claims originally made on the machine's behalf are equally curious. The first catalogue issued by the Remington Company, after stating that "The Type-Writer in size and appearance somewhat resembles the Family Sewing Machine" (an apt description of the original model) goes on to say, with rather more questionable accuracy, " . . . It is graceful and ornamental—a beautiful piece of furniture for office, study or parlor" While the average cross-Channel voyager would, I fancy, doubt the truth of the subsequent assertion: "Persons travelling by sea can write with it when pen writing is impossible."

From 1873 to 1879, then, the Remington occupied a unique position as the only typewriter made on a commercial scale. In 1879 it was joined by another of very different design—the first model of the Crandall type-sleeve machine.

Then came the Caligraph of 1880—an attempt to improve the Remington while at the same time evading the latter's patents—and the Hammond type-wheel machine of 1884. After that, in the words of "Alice in Wonderland,"

". . . . thick and fast they came at last,
And more and more and more. . . ."

By 1894, at which date my story really commences, the typewriter market numbered upwards of fifty different proprietary machines.

It is, of course, impossible in the time at my disposal to describe or illustrate to you all these machines; nor is it necessary. In the first place, over one-third of this total of fifty were "index" machines—a class of typewriter now in very little demand, and for which I cannot see much future. They principally flourished in the decade 1885-1895 (although the earliest commercial index machine, the "Hall," was introduced in 1880, while the idea can, as already stated, be traced back to the Burt "Typographer" of 1829) and they were, in effect, a retrograde step in typewriter evolution, since they sacrificed speed to cheapness. Although differing widely among themselves in mechanism, the general principle of all index typewriters is much the same. The types, instead of being separately brought in one motion to the paper by independent keys, form a connected block, which is moved as requisite by the operation of bringing an index-arm, or pointer, to the correct letter upon a stationary indicator-board. This done, a second motion is needed to print the selected type upon the paper. As compared with the ordinary form of typewriter, it is evident that much time is wasted in first selecting and then printing. At one time the index-machine was, to some extent, a serious rival of the ordinary typewriter, since the better-class machines of the kind were, while very slow in comparison, capable of producing work of equally good appearance, while they cost about one-third of the normal price; but many were mere toys, such as the "Ingersoll" and the "Eureka" or "Simplex," which is still obtainable—in toyshops. One or two better-grade index machines, such as the "Mignon" and "Frolic," are still on the market, and are, in themselves, exceedingly ingenious machines; but to my mind they are only suited to those who dabble in typing—not to the people who must make it their business. A devout pipe-lover once remarked, apropos of the cigarette, that ". . . it's a pleasant thing to smoke—when you're not smoking," and, similarly, my view of the index machine is, that it's an amusing thing to type with when you're not typing.

Apart from index-machines and from book typewriters such as the "Cash" and the "Fisher" (the last-named of which is, under the name of the "Elliott-Fisher," still enjoying a deserved popularity) the typewriters of 1894 fall into three main classes: non-visible type-bar machines, visible type-bar machines, and type-wheel machines. If we further eliminate all but the

leading machines of each class, a few slides will serve to exhibit the typewriters of 1894.

Taking first the non-visible, or "blind" type-bar machines, we begin, as is due, with the Remington No. 6 model, introduced in 1894. It is greatly, but still recognisably, developed from the first model. As in all the old "blind" style machines, the arrangement of the type-bars and platen can best be appreciated by imagining an ordinary pudding-basin, with a rolling-pin lying across the top of it. The type-bars form the basin, and are pivoted around its rim. On the depression of a key, the corresponding bar swings upwards, and the type meets the rolling-pin—the platen—vertically underneath its axis. In all such machines the writing, at the moment when it was written, was invisible, and only came into sight, by the gradual rotation of the platen, after some three or four more lines had been typed. If, by the use of a glass platen and transparent paper, one had actually been able to see the letters being imprinted on the paper, they would have appeared to be upside down.

In common with every Remington model from the celebrated No. 2 to the present day, this machine has a four-bank keyboard and a single shift-key. Each type-bar carries two types, selectively brought into operation by the shift-key, which moves the platen to or from the operator, and so determines which of the two printing-points shall coincide with the surface of the platen.

Of somewhat similar appearance, but differing considerably in its mechanism, was the well-known Smith Premier machine, first introduced in 1888. Mechanically, it was planned on exceedingly robust lines, being particularly remarkable for the shortness of its type-bars and the extraordinary length of their bearings, these being at least three times as long as those of the Remington, with a corresponding gain in rigidity and certainty of alignment. It may be noted that neither the Smith Premier nor the Remington machines of this date employed a guide for their type-bars when nearing the printing-point, but depended absolutely upon the rigidity of the type-bar bearings. Curiously enough, the original Remington—the Sholes-Densmore machine—had a form of guide, although this was actually nearer to the pivots than to the printing-point; but this was discarded in the Model 1 Remington, and did not re-appear in the Remington machines until very recently.

The Smith Premier was fitted with an unusual and very efficient form of shaft-drive connection from key to type-bar, which eliminated sub-levers (a similar plan was used on the first models of an excellent post-war Italian machine, the Olivetti), and it also differed from the Remington in that it had a full keyboard—that is to say, it had a separate key for every character that it printed, and, having only one printing-point, did not employ a shift-key. It may be noted that the first machine to have such a keyboard was the Caligraph, but in its original form (the makers afterwards adopted the plan of

re-arranging it to suit various customers' wishes), this was more of a liability than an asset, since the lower-case types occupied the centre of the keyboard, and the capitals, etc., were grouped higgledy-piggledy on either side. In consequence, to use the Caligraph at any speed it was necessary to memorise the position of every single individual key. The Bar Lock was the first machine to adopt the common-sense plan of a seven-bank keyboard, with the lower-case letters occupying the three lowest banks, the capitals duplicating their arrangement on the next three, and the signs on the uppermost bank, and this plan was followed in the Smith Premier, the Hartford, the Yöst and practically all other full keyboard machines.

Another machine, of even greater ingenuity than the Smith Premier, was the Yöst. Like the former, it was a full-keyboard, non-visible machine, but it embodied several novel contrivances. It discarded the usual inking ribbon, employing instead an ink-saturated pad, in which the faces of the types normally rested. The type-bars were quite loosely pivoted, and consisted of a set of jointed links which, on the depression of the key, withdrew the type from the pad, tilted its face upwards, and thrust it unerringly into the aperture of an exceedingly rigid central guide. Each type-face was exactly the same size, and had bevelled edges fitting the bevelled hole in the guide. The pad-inking and forced alignment of the Yöst enabled it to produce work of strikingly neat appearance, which fully justified the Yöst slogan of "The machine for Beautiful Work."

I turn next to the visible-writing machines of 1894. We are accustomed to think of the visible machine as a comparatively recent development of the typewriter, but actually the second commercial typewriter ever produced—the 1879 Crandall machine—was a visible writer; while the first type-bar visible machine was the little-known Horton, produced in Canada in 1885. Of similar type to the Horton, but much better known, was the Bar-Lock, which appeared in 1887. It was a full keyboard machine, with the printing-point, in the early models, situated at the exact top of the platen and the type-bars forming a vertical barricade between the printing-point and the operator. In this and similar machines, such as the Franklin, English, and early models of the Salter and Imperial, it was necessary to sit very upright for the writing to be really visible, and in later models of the Bar-Lock the type-bars were sloped slightly backwards in the same manner as in the Horton and the Condé (a little-known machine of the Horton type).

Another machine of 1894 which wrote on the top of the platen was Mr. Jenkins' own production, the "Waverley," which merits description both on that account and for its unusual design. The typebars were arranged vertically behind the platen, and struck downwards towards the operator. In theory this arrangement is attractive, but it has the grave practical disadvantage that the paper cannot possibly be led upwards off the platen, but must be wound into a container; so that while you can read with perfect ease what you

are writing, you cannot read at the same time the lines already written without taking the work off the machine. This insurmountable defect proved fatal to the Waverley and to the other three machines of the type, the Brooks, North and Fitch (the last-named being one of the cleverest, lightest, and noisiest machines that I have ever seen), and it probably was also responsible for the ultimate disappearance of the well-known Williams, a machine with two sets of horizontal "grasshopper" typebars arranged one on either side of the platen.

The Waverley presented several other features of interest. The space after a word could be made simultaneously with the last letter, while the vexed question of full-keyboard *versus* shift-key was met by a typically British compromise combining the defects of both arrangements with the merits of neither, the machine having seventy-six typebars operated by thirty-eight keys and a shift-key.

But the principal feature of the Waverley was its differential spacing, a point which seems almost to have fascinated the early British typewriter inventors. Although starting much later, this country has produced at least three differential-spacing machines—the Daw and Tate, Waverley and Maskelyne—to America's two—the Crandall and Columbia (I exclude the Thurber "Chirographer" of 1846, as this was not strictly a typewriter, but a writing-machine, which drew each letter separately on the paper in pencil). America, however, must have the credit of having recognised sooner than we did that however admirable in theory, differential spacing is, in practice, an expensive luxury which is out of place in a modern typewriter.

Briefly, a differential-spacing typewriter is one designed to produce writing which closely resembles printing; a feat which the ordinary typewriter signally fails to accomplish. To the eye of a printer, accustomed to "justify" the spaces between his types, the spacing of such a machine, which allots the standard tenth of an inch impartially to a full-stop or to a capital W, is simply appalling. The Waverley attempted to remove this defect by an escapement which provided three different widths of spacing, in the proportion of 1, 2, and 3; 1 for stops, 2 for ordinary letters and 3 for the wide letters, m and w. Another machine, the Maskelyne of 1889, went still further, and provided four spacings, in the proportions 1, 2, 3 and 4; 1 for stops, 2 for narrow letters such as i, and l, 3 for normal letters such as a and p, and 4 for m and w. As it inked from a pad, like the Yöst, and not through a ribbon, the impressions of the types were very sharp and clear, and there can be no doubt that when the Maskelyne was operated with clean type and at a moderate speed it produced work which was almost a facsimile of printing, and which stood out, as a matter of calligraphy, a long way beyond anything accomplished on a typewriter before or since. But the machine was altogether too delicate and complicated to stand the rough-and-tumble usage of commercial employment. In addition, differential spacing has a practical defect. The best typists—the present company always excepted—occasionally make mistakes, and strike wrong letters. In the

ordinary way, since each letter is allotted the same space, there is little difficulty in making the correction. But if on a differential spacing machine one made a very common mistake and wrote two ns for two ms, there would only be room for one m after erasing the ns, and the whole word would have to come out.

The remaining principal machines of 1894 can be briefly dismissed. The Oliver and the Empire, which had then just been put on the market, are still with us, not greatly altered, as are the two principal type-wheel machines of that date, the Hammond and the Blick (which, after disappearing for some years, has just been re-issued by the Remington Company). In consequence, I propose to discuss them when dealing with the machines of to-day. Now, let us consider the principal changes which have come about between 1894 and 1928.

The most important change has undoubtedly been the rise of the "front-stroke" machine, which has gradually but surely swept all but a very few survivors of the 1894 machines into limbo—or the Science Museum. Broadly speaking, a front-stroke machine is one in which the printing-point is at the front of the platen, half-way between top and bottom. Strictly, this definition would cover those "thrust-machines" such as the Empire, in which the type-bars do not swing about pivots, but slide straight forwards against the platen. The term, however, is generally restricted to machines having pivoted type-bars.

Actually, front-stroke machines were already known in 1894. The two earliest machines of the kind, neither of which was made commercially, were the Prouty and the Grundy, both patented in January, 1887. After these came the Daugherty machine of 1890, known later as the Pittsburg and still later as the Reliance. But the first machine of the kind to achieve extensive success was the Underwood of 1898, and it is undoubtedly the prototype of almost all the machines of to-day. It was invented by F. X. Wagner, who afterwards designed the Continental typewriter.

In front-stroke machines the type-bars can no longer be arranged, as in the old "blind" machines, with their pivots forming a complete circle; this is reduced to a sector, and the width available for the bearings is considerably diminished in consequence. This would, in itself, make for bad alignment, and in consequence a guide is almost always adopted to prevent a sideways motion of the type-bars, and sometimes a comb also. Some attempts have been made to avoid the need for a guide by "staggering" the bearings on both sides of the sector—the Remington machine did so until very recently; but the victory of the single sector and central guide may now be regarded as practically complete.

The adoption of the front-stroke principle necessitated another marked change—in the ribbon mechanism. In the old blind machines the ribbon, an inch or more in width, lay horizontally underneath the

platen and meandered peacefully backwards and forwards, its position being practically unaltered, laterally, from one stroke of the keys to another. But a ribbon mechanism on such lines and applied to a front stroke machine would make the ribbon, if it were led vertically as in the Prouty, hide the word actually being written ; while if the ribbon were horizontal it would hide the whole of the writing-line. Accordingly it was found necessary to pass the ribbon, close to the printing point, through a vibrating guide which, at every stroke of the keys, should lift it in front of the type and then drop it again to disclose the imprinted letter. It was also perceived that by altering the lift of the ribbon it was possible to use different portions of the ribbon, which might be of different colours, while it was obvious that to avoid excessive travel of the vibrator, which meant extra load on the key and hence a heavier touch, the width of the ribbon should be reduced as much as possible. It follows that the ribbon mechanism of a front-stroke machine is necessarily much more complicated than that of the old blind machines. It may be noted, however, that in the French Japy front-stroke machine (formerly the Remington-Sholes) the ribbon mechanism closely resembles that of the blind machines, no vibrator being employed.

By 1907, in which year the L. C. Smith, Smith Premier and Remington firms had brought out front-stroke machines, to be followed soon after by the front-stroke Yöst model, it was obvious that the day of the " blind " machine was done. The adoption of the front-stroke principle also hastened the disappearance of the full-keyboard. To produce a front-stroke full-keyboard machine was a mechanical problem of great difficulty—so far as I know, only one machine of this type, the Smith-Premier No. 10, has ever been put on the market. It was an excellent machine, but it was withdrawn about three years ago and is not likely to be resuscitated.

There was another, and more important cause, hastening the departure of the full keyboard ; and that was, the rise of the " touch " system of typing, in which the typist, like a skilled pianist, never looks at the keyboard. First used by a self-taught American typist, Charles McGurrian, about 1878, it is now an essential part of the equipment of every skilled stenographer—but it is difficult, if not impossible, to employ it with a full keyboard. In addition, one of the " talking points " of the full keyboard machine—the greater ease with which complicated tabular matter, requiring repeated shifts, can be typed—has been reduced in importance by the great development of tabulators : devices by which the carriage can be moved automatically to any one of several selected points in its run—or, with the more complicated tabulators, such as the " decimal " type, to a point at selected number of spaces in advance of those fixed positions. Practically every modern standard typewriter can be obtained fitted with a tabulator.

The " blind " typewriter, then, has gone from among us ; so has the full keyboard. So, practically, have all methods of inking other than by a ribbon :

which last method, it may be noted, was not only used in the earliest Remington, but even before—it is to be found in the Francis typewriter of 1857 (which, had it not been for its piano keyboard, might have achieved some success). I say practically, because, although pad-inking has died out with the Yöst, roller-inking is employed in the Blick, which, as I remarked earlier, is once more on the market. Roller-inking has been used in one or two type-bar machines, such as the Fitch and the Sun, but although it makes for sharper printing it is distinctly more troublesome to keep efficient than a ribbon.

Harking back for a moment to the subject of keyboards, it may be noted that although the battle between the shift-key and the full keyboard has been decided in the former's favour, that between the single and double shift is still in progress. There may even be other contestants, since at least one machine, the German "Helios," has a triple shift. I confess, however, that I cannot see that such an arrangement has any real *raison d'être*. With a triple shift, you must either have a quite unnecessarily large number of types, or, if you use less than twenty-six keys, you must shift even to obtain some of your ordinary lower-case letters—an intolerable nuisance. At present the four-bank keyboard with single shift is standard for all front-stroke office machines, and for many portable machines, while the three-bank keyboard with double shift is used in four office machines—the Hammond, Empire, Oliver and Allen—and in most of the remaining portable machines.

As you will see by the examples shown, the wide diversity of the office machines of 1894 has disappeared, and in their place we have machines bearing a close family resemblance, and forming a type which it is, I think, only fair to classify as the Underwood type. Whether manufactured in this country, in U.S.A., or on the Continent, it presents much the same characteristics—front stroke, narrow vibrating ribbon, visible writing, and four-bank keyboard with single-shift. There are, of course, detail differences in the various machines—but it is difficult to avoid being struck by their close family resemblance. The most pronounced mechanical difference is, that unanimity has not yet been reached on the question of whether the shift-key should operate by moving the platen or the type-basket. In the majority of cases, the type-basket is a fixture, and the platen moves; but in three well-known machines, the L. C. Smith, the Smith Premier, and Bar-Lock, the platen can only move horizontally, and the shifting is accomplished by raising the whole type-basket.

If we merely count noses, the three last-named machines are out voted; on the other hand, it is true that when operating a machine with a wide and heavy carriage—a brief machine or larger—it is distinctly a saving of labour to have a shifting type-basket. There is, however, a slight theoretical disadvantage in this plan, and it is this: The spread of the keys, in all machines, is much wider than that of the pivots, and the motion of the keys must therefore be conveyed to the type-bars by some system of bell-cranks or links which, in plan, gradually tapers inwards. I may mention that the planning of type-bar

and sub-lever systems offers some fascinating problems in projective geometry. The more regular this tapering the more efficient, broadly speaking, can be your system of bearings around which the sub-levers operate. Now in a machine with shifting type-basket there must, if your alignment is to be undisturbed after shifting, be some place at which, for an inch or more, the tapering ceases and the sub-levers or links run absolutely parallel; which means that at all other places in the system the degree of tapering must be slightly greater than it would be in a machine with fixed type-basket and shifting platen. That is, however, a matter of little practical importance.

Apart from this well-marked class of front-stroke machines there are four others, all of them marketed both in 1894 and now, which diverge widely, in mechanism, both from the accepted type and from each other. That they have held their ground so long is evidence of strong vitality, since, as we see in the evolution of the motor-car and of many other mechanisms—and even in matters quite unconnected with mechanism—it is generally unwise, and frequently fatal, to stand too far aside from the common run.

These machines are the Hammond, Blickensderfer, Empire and Oliver. The Hammond, first introduced in 1884, is a type-wheel machine, in which the types are arranged on the circumference of a wheel which oscillates horizontally. When, by pressing a key, the selected letter has been brought opposite the printing-point, a hammer strikes the paper at the back and presses it against the type. Whatever the force on the key, that delivered by the hammer is constant—as a clockmaker would put it, the action is that of a remontoire. Owing to this arrangement, which necessitates always striking the keys a little harder than is absolutely necessary, and to the great inertia of the type-wheel as compared with that of an ordinary type-bar, it would be thought that the touch of the Hammond was necessarily heavy, but from my own experience I can testify that this is by no means the case. Like practically all type-wheel machines, it has a double-shift keyboard, and admits of a rapid substitution of the type-wheel by another bearing a different style of type; but it is unique among typewriters in that two styles of type are available simultaneously, and can selectively be brought into action in a few seconds.

The Blickensderfer machine, whose formidable name is generally and mercifully abbreviated to "Blick," is also a type-wheel machine, but although it possesses many good points it is mechanically inferior to the Hammond since the depression of a key not only rotates the type-wheel, but also strikes it against the paper. Owing to the inertia of the type-wheel, and to the friction necessarily involved in this combined motion, the touch is distinctly heavier than that of a normal machine. Like the Hammond, it admits of a ready change of type.

The Empire (Adler) is a thrust-machine. The type-bars are not pivoted but are arranged fan-wise and slide forwards, horizontally, until the types meet the platen. The action is strong and simple. In the original

Empire (made in Canada), which is, I believe, still on sale, but no longer manufactured, a double-shift was employed, the angularity of the outer type-bars making it difficult to use a single-shift: but this feat has been accomplished in the latest models of the Adler, which has always been, practically, a German Empire—and is now the only one.

The Oliver is of unique design. The type-bars are shaped like inverted U's, and arranged in two banks one on either side of the platen, striking downwards on to its top. It is, in fact, the last survivor of the "top-strike" machines so much in evidence in 1894. While this plan makes for a most rigid pivoting of the type-bars, the inertia of the latter is considerable, although this has the advantage of making the machine a most powerful manifolder. It would not, I think, be easy to convert the Oliver into a single-shift machine.

Of the various portable machines I have little to say, and that little can best be said when I touch on future developments. As a class, they are most efficient machines, fully capable of doing the work and sustaining the reputation of their big brothers.

The examples which I have given do not, of course, cover all the varieties of the modern typewriter. Many of these must, unfortunately, be dismissed with very brief mention. There is, for example, the Elliott-Fisher machine, in which the platen is stationary and the type bars travel across the paper—an old plan which, it is interesting to note, was employed in a very early machine—that of Progin, patented in 1836. Owing to this construction it is particularly adapted for writing in the pages of bound books—a proceeding which, in some countries, is necessary in order to comply with the laws governing the keeping of accounts. There are also several types of adding and computing typewriters, such as the Moon-Hopkins, the Ellis and the Remington accounting machine—all of very great ingenuity. Again, there are machines designed to type in various systems of shorthand, amongst which I must particularly mention the Stainsby-Wayne embossing shorthand typewriter for the blind, which performs the almost incredible feat of enabling a blind stenographer to take dictation in shorthand, and subsequently type it, as readily as if he were possessed of full sight. This is, in my judgment, one of the greatest benefits which Man has yet conferred upon his blind brother.

But the time at my disposal admits of little more than a description of the standard office machine of to-day, and a short enquiry, upon which I now propose to enter, as to in what way it can still be improved. It does not, of course, follow that, even if my predictions happen to be well founded, the evolution of the typewriter will necessarily conform with them. There are many other factors besides mechanical ideals to consider; in particular, commercial expediency and the necessity for producing a machine at a competitive price. Many machines, in themselves excellent, have ceased to be made because their manufacturing cost was too high, and this is a factor which, it appears to me, is very strongly in operation at the present time.

The modern typewriter, taking it all round, is a very efficient piece of mechanism. Broadly speaking, there are no bad typewriters. In my judgment the worst machine of to-day (whose name wild horses shall not drag from me) is capable of a performance which would be regarded by the makers of 1894 as practically perfect. Still, it is worth enquiring in what directions there is yet room for improvement, and the main lines of the enquiry seem to me to be three—speed, noise and convenience.

Of these I think speed, *per se*, is the least important. It has been often shown, in competitions, that the standard machine of to-day is capable of being operated, for long periods, at speeds of as much as 150 words per minute—and this when typing from unfamiliar printed copy with a deduction of five words for each mistake, not, as in former days, merely repeating some easily-memorised sentence such as, "Now is the time for all good men and true to come at once to the aid of the party." It would seem that so far as the achievement of speed is concerned the limiting factor is not the capacity of the machine but the ability of the operator.

Well, we are not all expert typists, and even the expert, I think, would welcome some means of relieving her or him from the incessant strain, both muscular and mental, involved in long spells of typing at high speed. In consequence I foresee an increasing future for the electrically-operated typewriter, in which electric power is used to do the "donkey-work" under the operator's direction. Electric typewriters, of course, are not things of to-day or even of yesterday—an electrically operated typewriter was patented by Edison in 1872; one form of the Hansen Schrieckkugel was operated by what was then called an "electro-magnetic machine"; and the Cahill of 1899, the Faber of the following year, and the Electric Blick of 1907 were all of this class. Such machines, however, belong to a past age, and are quite outclassed by the modern machines which have appeared recently, such as the Mercedes-Euklid, Remington and Woodstock electrically-operated models. There is also the Hammond "Varityper" electric machine, but here I am on rather dangerous ground, since I am not absolutely certain how this works, and I have not yet met anyone who could tell me; in fact, my state of mind on the subject is reminiscent of the schoolboy (not Macaulay's) whose answer to the question, "Define the Theory of Exchange," ran as follows:—"This subject, as I understand it, is not very well understood." So far as I can see, in the ordinary Hammond the hammer which brings the paper to the type is first cocked and then released by the key; in the Varityper the cocking is done by an electric motor which operates intermittently, keeping the hammer spring at a previously-determined tension, while the work done by the operator via the key is reduced to rotating the type-wheel and releasing the hammer. If I am right, the machine is really spring-operated, in contradistinction to the other machines I have mentioned, in which electric power is used to rotate a cylinder, to which the type-levers are intermittently connected by means of friction-cams.

It may be objected that the use of electric power in a typewriter is an unnecessary luxury, as well as an additional complication. I am not of this opinion, nor can I see why one should compel a typist to do what a motor can do better and more uniformly. If I may use the analogy, some of you may perhaps remember the sensation caused in the car world in 1913 by the advent of the electrically-started Cadillac—"The Car without a Starting Handle." The electric starter, in those days, was generally regarded as a useless luxury for which there was neither need nor justification, but to-day we expect to find, and do find, it fitted as a thing of course in cars of all kinds, sizes and prices. I instance this as showing that the luxury of one day is often the necessity of the near future—and so, I think, will it be with the electric typewriter.

It is interesting to look back on some of the earlier ideas for increasing speed. Several machines, such as the Duplex, Century, Bracklesberg and Universal have been designed to write two or more letters, or even short words, at one stroke—one, the Xcel (a later form of the Bennington, writing about twenty short, common words such as "the," "and," "but," "is," etc., at a single blow each) was put on the market quite recently—but I can see no future for the idea. The selection of the keys in such machines burdens the mind of the operator, and tends to reduce speed rather than increase it.

Connected with the question of speed is that of the keyboard. As I stated before, the four-bank keyboard with single shift-key is standard in the majority of machines; but it is possible that the three-bank with two shifts may, as reducing the cost of the whole machine, yet prove a serious rival.

I am afraid that we shall never escape from the present arrangement of the letters on the keyboard. I say escape, because there is no doubt that it is very far from being the best possible arrangement. So far as I can see, it owes its existence to the mechanical difficulties experienced by Sholes in designing his early machines (for it is a remarkable fact that the keyboard of the Sholes-Densmore machine of 1873 is practically identical with that of the present Remington and all other modern typewriters). Apparently Sholes found that his circularly-arranged type-bars were apt to clash and stick, and accordingly he so disposed his types that letters which commonly occurred together were on type-bars as far remote as possible. Theoretically he could still, by suitable connections, have arranged his letters as he liked on the keyboard; but practical difficulties, such as the angularity of the connecting wires, stood in the way, and in the event the arrangement of the types on the type-bars definitely controlled that of the letters on the keys. This, at least, is the best explanation I can offer of the present keyboard. It certainly is not founded upon the arrangement of a printer's case, as has sometimes been stated; nor upon any principle of frequency or convenience. For example, if there are any two letters in English which (except when transliterating from Arabic) are always found indissolubly connected, they are q and u; yet at

present they are separated by two-thirds the width of the keyboard. Again, the commonest letter of all, e, has to be operated by the middle finger of the left hand, instead of the better-adapted first finger.

Of course, there is actually no perfectly-standard keyboard at present, even for Latin languages. A French typewriter, for example, has no w, and puts the z where the y is normally. Even in America, where most of the people speak a language closely allied to English, a keyboard differing slightly in the arrangement of the signs is employed.

Many attempts have been made to produce better and/or different keyboards: the Crandall, Fitch and Blick are examples. In the last-named, it was claimed with truth that 70% of the letters in any ordinary piece of writing could be written by the bottom bank of keys—D H I A T E N S O R. The best-known alternative keyboard, probably, is the Hammond "Ideal Keyboard," which was long on the market, and even fitted in one or two other machines. In my opinion, however, it was fatally handicapped: not only by the long start gained by the usual QWERTYUIOP keyboard, but also by the fact that its keys were arranged in a curve convex to the operator.

Such convex keyboards, apart from any question of the arrangement of the letters of them, have always proved failures, and those machines which employed them, such as the English, Franklin, Salter, Imperial and others have invariably been compelled, if they survived long enough, to replace their curved boards by the usual straight line arrangement. The reason for this is obvious, since a convex board necessitates a wider stretch of the hands and an unnatural disposition of them. Actually, if a key-board were designed to conform with the normal position of the finger tips, it would form two concave curves. In addition, a straight-line arrangement of the keys facilitates "touch" typing.

Now for the subject of noise. It will, I think, be admitted that most typewriters are noisy; and, so long as the types are brought into contact with the platen by a straight forward blow they will continue to be noisy. The type-bars have, of course, inertia—they have to start from rest, and they must be brought to the platen quickly. The effort to overcome their inertia is much greater than the force required merely to imprint the letter on the paper, and this surplus force is partly employed in causing noise. The ideal plan, I suppose, would be to have a rolling contact between the type and the paper; but although this plan has actually been employed in two machines—the Addey and the Soblik—neither met with enough success to justify a repetition of the experiment.

Some firms make "quiet" models of their machines, in which care is taken to eliminate mechanical noise as far as possible—which, with the normal type of machine, is not very far; and various sound-proof casings have also been devised to fit over typewriters, leaving only the keyboard exposed. These, however, are necessarily cumbersome, since they have to be something like three times the width of the machine; and, in addition, they do not completely

effect their object. Sound, as any architect will tell you, is capricious, and it is not easy to predict the effect produce by any container, whether as small as a box or as large as the House of Commons, upon the volume of sound emitted by any source of noise, such as a typewriter or a politician, enclosed therein.

There is, however, one remarkable machine now on the market, the Remington Noiseless (formerly the Noiseless) typewriter, in which the question of eliminating noise has been approached from quite a fresh angle. In this machine the types are not brought to the paper by a freely-swinging type-bar, but by a toggle action which squeezes them on to the paper, and in which the printing is effected by the momentum of a small weight and is, to a large extent, independent of the pressure exerted upon the keys. *Inter alia*, this toggle action slows up the speed with which the types approach the paper, and compels them to travel a definite and limited distance; if the platen, whose position is adjustable to and from the operator, be withdrawn a little too far, the types will not reach the paper at all.

The Noiseless is so different from all other machines that it is difficult, at first trial, to appraise it correctly. The touch, for example, is quite unlike that of any other machine. There is no doubt that it has already attained a considerable measure of success. It is unquestionably much more silent than a standard machine, and a working speed sufficient for all ordinary purposes can be reached with it. Moreover, although it might be thought that with the toggle action its manifolding powers must suffer in comparison with those of a machine of normal type, consideration will show that if the distance of the platen be correctly adjusted (as it can be) the pressure available is actually more than in an ordinary machine.

On the other hand, while quiet it is distinctly audible. I remember, some years ago, seeing it for the first time at the Business Efficiency Exhibition. I asked the attendant to demonstrate it, which he willingly did. After he had rattled off a few lines, I felt compelled to remark, "Well, it's not really silent." "Oh, no, sir," he replied, "we don't claim that it's *silent*. We only claim that it's *noiseless*." I imagine that, to him, "noiseless" and "less noise" were synonymous.

Also, it has a slight mechanical disadvantage compared with the normal typewriter. It is a thrust-machine, and, like all thrust-machines, only one type-bar delivers its thrust at right-angles to the platen; the remainder strike it at various angles ranging down to 45°; in other words, the type carried by the outermost bars is, as it approaches the paper, moving as much along the platen as towards it. This angularity, however, is reduced as far as possible by the very ingenious structure of the typebars, of which there are only twenty-two, each carrying four types. Of these four, two are selected by the type-bar mechanism itself, each type-bar being connected to two keys; the other two are selected by the shift-key.

The action is a little reminiscent of that employed in another thrust-machine now obsolete, the Ford, or Hurtu. The type-bars are necessarily of complicated structure, and each type-bar action has some twenty additional pivotal points, each with its slight added increment of friction.

I would not have it thought that I wish in any way to decry the Noiseless machine. Mechanically, it is most ingenious; and, as I say, it has already obtained a considerable measure of success. I hope that it may be found possible to perfect it still further. I should much like to see an electrically-operated model.

Leaving the question of noise, I turn to that of convenience. There is one point in which it has always seemed to me that the ordinary front-stroke machine could be much improved. That is, the position of the writing-line. No one of ordinary build can look straight at the front of the platen; he looks down on it at an angle of roughly 45° . Then, why not arrange that the writing-line shall be in that position, and so view the writing squarely, instead of looking at it obliquely downwards? It may be argued that this is unimportant, since with the ordinary front-stroke machine the writing is legible enough, and all but the last written line or two is offered to the eye at the correct angle. But it must be remembered that it might similarly have been argued that an expert typist would not need to see the writing at all (which is true)—still, this did not save the "blind" machine. The thing has been done—several machines, such as the Triumph Visible and the last model of the Salter, have been designed to write at the correct angle: and although it might be said that these machines were bulky in comparison with those of the normal type, the same could not be said of machines such as the German "Mentor," or the Swiss "Sphinx," also of the same type. It is significant that in portable machines which are, as a class, used much more by amateurs than by expert typists, this principle is making headway—in the Corona, for example, the writing angle is about 38° above the horizontal, which is not far from the theoretical 45° . I believe that in time the majority of machines will be designed to write considerably higher up the platen than they do at present.

As regards portability, while the standard office machine (for which a certain weight is really an advantage) offers probably few opportunities for weight-reduction, much has been done in the field of portable machines towards reducing both the weight and the bulk of the machine. As regards the latter point, the Royal and Underwood portable models are examples of what can be done without departing from the lines of the ordinary front-stroke machine; the Corona four-bank model, as I previously remarked, approximates to the perfect writing-angle and yet is by no means bulky; while the Remington Portable (equipped with a standard keyboard) and the three-bank Corona are the least bulky of all. In the last two machines, however, special construction is employed. In the Remington (and also in the French "Celtic" machine) the type-bars, in the carrying position, lie flat, and are raised to a higher

position when preparing to write: this being rendered possible through their operation being effected by toothed gearing instead of links. In this machine the writing-angle is about 75° above the horizontal, or not far from the top of the platen. In the three-bank Corona, and similar machines, the platen in the carrying position folds over the keyboard. A somewhat similar device is used in the portable Hammond. In general, there appears at present to be more liveliness and variety in the design of portable typewriters than of office machines.

Of minor devices for the typewriter there is no end. It has often been suggested to embody a word-counter in the machine, but although many such devices have been patented, and one typewriter, the "Crown," had a word-counter built in as a standard feature of the machine, they have never caught on. They have generally been designed to be operated by the space-bar, which means that for their indications to be accurate you should not use that bar for any other purpose than making spaces between words—a rather hampering restriction.

I saw it suggested the other day by the winner of a typing contest that it would be an improvement to fit the modern typewriter with an erasing key. Such of us as are not expert typists will no doubt sympathise with this requirement; but while it is mechanically possible to satisfy I confess that I do not regard it as a likely development.

Finally, the question has sometimes been raised whether it will one day be possible to eliminate the "personal equation" in typing by producing a perfectly automatic typewriter which will take dictation without the intervention of a human operator—just as that curse of modern life, the wool-gathering telephone operator, is being steadily replaced in London by the (to all appearances) equally erratic automatic telephone. Well, I consider that the thing could be done, but I do not think it could ever be worth doing, and it certainly has not been yet—although on this point I once heard a story of which I can only say, in the words of a well-known misquotation, "*Si no è Verdi, è ben Traviata.*"

It appears that some years after the War a foreign inventor took a suite of rooms in a fashionable New York hotel in order to demonstrate an automatic typewriter. The appearance of the machine was most impressive. It occupied a table about as large as a billiard-table. At one end of this was an armchair, and facing this a switchboard and a large trumpet, into which one spoke. In the centre portion of the table were located a battery of accumulators and several strange pieces of mechanism, chiefly composed of sets of discs carrying letters engraved on their edges. During the operation of the machine these were in constant irregular movement. At the far end of the table stood a typewriter, its keys operated by an electric motor.

Visitors were invited to sit down in the chair, press the starting-switch, and see the machine take down their dictation automatically as fast as they cared to deliver it. It was explained before starting that while the machine would

spell all ordinary words correctly, unusual ones and words of similar sound but different spelling should be spelt out letter by letter. What the machine would write if one sneezed into it, or addressed it in Chinese, I have not ascertained. Its operation seemed to be perfectly satisfactory, and while its cost was, of course, much higher than that of a normal typewriter, it was estimated that if one capitalised the wages of a typist the machine would prove, in comparison, much the cheaper bargain of the two.

So highly did the business world think of it, that a syndicate to buy the rights was speedily formed and the large amount required over-subscribed. Unfortunately it was subsequently discovered, too late to intercept the inventor, that the typewriter was really worked by a concealed operator in an adjoining room, the trumpet into which the dictation was made being actually the transmitter of a telephone communicating with him.

In concluding this inadequate sketch of a complicated subject, will you permit me to say how gratified I am to have had this opportunity of laying before you my views, however partial and ill-considered, upon a matter in which I have long been interested.

DISCUSSION.

THE CHAIRMAN was sure that everyone would agree that Commander Gould had given a most masterly summary of the very large number of typewriters that were still in existence or recently had been. The author had described a bewildering number of typewriters, and had brought out the points in which they differed from one another, and the essential principles on which each of them was constructed. Some of those present could speak with much greater authority on the typewriter than he could, and he hoped they would presently join in the discussion of the points raised by Commander Gould.

The typewriter was a most interesting piece of mechanism, which had developed very rapidly, as the author had shewn, because in these days it was an absolutely essential piece of office equipment. It was due to this, no doubt, that the various types had been created and were competing with one another in what was, he understood, a very severe competition. As the author had said, it was not merely mechanical efficiency that decided the matter; cost, convenience, and the individual choice of those who used the machines also played their part.

He hoped those present would examine the very instructive series of writing machines which were before them. For his own part, he was very much interested in the mechanically driven typewriter, with which so far he was not acquainted.

MR. PARKER DRAKE (Chairman, Typewriter Trades Federation) said that the paper dealt with a subject in which his Federation was naturally very much interested. To be perfectly frank, when the Federation received the very kind invitation of the Society it did not know exactly how to take it—a lecture upon the probable future of the typewriter! He would ask them to put themselves in the position of a man in Newcastle who was invited to hear a man from Egypt lecture on the probable future of coal. Naturally, the Federation thought that the probable future of the typewriter would be safer in the hands of the Typewriter Trades Federation than, perhaps, in the hands of H.M. Navy. But he must say that he

came to the present moment duly chastened. He had listened to a paper upon the history of the typewriter—he had heard a great many in his time—which was replete with detail, and not a single mention had been made of historic fact which was not accurate.

He was particularly interested in the early part of the lecture, in which the names of Densmore and Sholes were coupled in connection with the Sholes-Densmore Model. The omission of the name of Densmore was a mistake that was very frequently made by those going back into the history of the typewriter. Densmore was just as important in the partnership which resulted in the first Remington Model as Sholes. As a matter of fact, he had intended mentioning Amos Densmore in connection with the question of the standard keyboard which was raised by the lecturer. Amos Densmore was responsible for the present standard keyboard, which in all probability would never be changed.

Some of the pictures which the lecturer had shown on the screen illustrated the various attempts which had been made at making the print of the typewriter justify itself in the same way as in ordinary printing. Many patents had been taken out in the last fifty years to achieve that end, but none of them had ever been successful. He was inclined to think that the reason for their non-success was that there was no need for such justifying. Letters spaced at twelve to the inch, ten to the inch, or nine to the inch, met all commercial needs, and the necessity for justifying had never been sufficiently felt. Even when newspapers and magazines had been published from typewritten copy during strikes the justifying had been sufficiently accomplished with the even spacing of the letters to meet all actual needs.

Commander Gould had mentioned a very old friend of his, Charles McGurrin, as being one of the first operators of a double keyboard machine. As a matter of fact, Charles McGurrin was never favourable to the double keyboard. Long before Office Equipment Shows were held in New York, London or Paris, Charles McGurrin was recognised as the world's record typist and the world's champion typist. That was going back some thirty years. Up to that time (nor for some years later) there had never been any Convention or Association for the purpose of bringing typists together from all over the world in a competition which would justify the title of champion typist. Charles McGurrin was a Court reporter, and was, he thought, the first person to learn how to use a typewriter without looking at the keyboard. McGurrin had never been credited with it, but he was probably the pioneer of what was known to-day as touch typing.

Turning to the main subject of Commander Gould's paper, the probable future of the typewriter, he entirely agreed that improvement should be along the lines of speed, noiselessness and convenience. In regard to speed, every modern typewriter would write faster than the average typist could spell. That was really the limit of speed. The measure of the typist's total capacity was spelling, and unless some psychical mechanism could be developed to enable the typist to spell at a tremendously higher speed than was now reached, the record of 144 words a minute, which really represented a greater phenomenon in spelling than in typing, was about the limit.

He wished he could follow Commander Gould into the question of the electrical typewriter. He agreed with Commander Gould at once in what he had said about the noiseless typewriter. Unquestionably one of the practical developments of the future would be along the lines of noiselessness, though he very much doubted whether it would be along the lines of electricity. Everyone knew that momentum was a far more potent force than electricity, and they probably knew as little about it as they knew about electricity. Very little was known about momentum in

typewriters, and he was inclined to think that future development in typewriters on the designing side would be along the lines of controlling the force of momentum. There were machines in which distinct developments along these lines were being made to-day.

He would like to say a word in conclusion about the standard keyboard. There was no question that the standard keyboard was anything but scientific, but, as he had already said, he thought it would always be used. If anyone could see how to get away from £ s. d. and to replace it by the decimal currency in this country, a way, might, perhaps, be found of getting away from the standard keyboard. But very few people knew that the standard keyboard of the typewriter originated in an attempt to overcome a mechanical defect. This, of course, was before the name "Remington" was given to what was really the first Remington Model. When Densmore and Sholes developed their first model, which ultimately became the Remington, they experienced great difficulty from the clashing of the bars in the basket when they tried to get up what was then a moderate speed. That difficulty did not exist to-day, but it was then a very real one. Densmore and Sholes conceived the idea of mitigating the difficulty by arranging the keyboard so that the letters which came most frequently in succession in the English language should be as far apart as possible in the basket of the typewriter. Amos Densmore had a son-in-law who was at that time a superintendent of schools in Western Pennsylvania, and was, presumably, the most learned man Densmore and Sholes could call upon or had access to; so they got him to make a list of the frequency with which the letters of the English language occurred, and that list was the basis of the present standard keyboard. He had had that personally from this one-time superintendent of schools, Amos Densmore's son-in-law, who subsequently became President of the Densmore Typewriter Company.

MR. E. PITMAN could see one practical difficulty in the reproduction of spoken sound by any form of mechanical typewriter, inasmuch as the spelling of English words differed so largely from the sound that there was very little connection between the two. He thought, therefore, there was a fundamental difficulty in the way of any inventor ever working out a machine which would record spoken sounds in the form of the very erratic English spelling.

MR. F. HOPE-JONES, M.I.E.E., F.R.A.S., wished to ask some questions which he had no doubt Commander Gould or the Typewriter Trades Federation would be good enough to answer. Why was there no differential spacing between the lines of a typewriter? Why was it that if one wanted to use a sheet of ruled foolscap on a typewriter it was ninety-nine chances to one against the spacing coinciding with the lines on the foolscap paper? Why could not he enjoy now the conveniences which were provided twenty-five or thirty years ago by the little Blick? The little Blick simply had a milled nut at the end of the cylinder instead of a ratchet wheel. The ratchet wheel seemed to be in common use now, and one, two, or three teeth could be picked up by that wheel for single, double or triple spacing. If his memory served him, the slogan—to use a word which he did not like—of the Blickensderfer people was to the effect that the machine weighed seven pounds and cost seven pounds. He was little more than a schoolboy, quite a young man at any rate, setting up in business for the first time, and making his first purchase of a typewriter at the time—about thirty years ago. His business was made on that machine, with a Board School boy at five shillings a week to work it.

LIEUT.-COMMANDER GOULD, R.N. (Retd.), in replying to the discussion, feared that Mr. Parker Drake had misunderstood his remarks about Charles McGurrian. He did not say that Charles McGurrian used a machine with a double keyboard, inasmuch as he happened to know that Mr. McGurrian's first machine was a Remington and that the next was a Remington-Sholes. He remembered seeing in Dupont and Canet's book a picture of Mr. McGurrian seated at a Remington-Sholes machine. He remembered, also, that Mr. McGurrian met, among others, an operator using a double keyboard machine, and beat him easily, the remarkable point being that his victory was greater when typing from printed copy than when typing from dictation, because the other man had, as it were, to take in an eyeful and then go to the keyboard.

In regard to Mr. Parker Drake's suggestion that no account of the origin of the standard keyboard was given in the paper, his intention was to make practically the same explanation of its origin as Mr. Parker Drake had given, but he did not think it was of very great interest and, being pressed for time, omitted it. He hoped that Mr. Drake would accept his assurance that the conclusion he had reached was practically the same as Mr. Drake's.

In reply to Mr. Pitman, while an automatic typewriter was an undoubted possibility, there was no doubt whatever that it would have to be a machine of such enormous size, weight and complication that it could never be of any commercial value at all. He calculated that its dimensions would be somewhere in the neighbourhood of 10' cube, which was scarcely a practicable size.

Mr. Hope Jones had mentioned differential ruling. It was possible, of course, to add a differential ruling arrangement to the mechanism of the typewriter, but he confessed he could not see that it would be of much practical value. The platen of any ordinary machine could be so turned that the type would hit any line upon it, so there was no point at all in having a differential ruling arrangement. One could load a typewriter with many things which were not at all necessary, and which only tended to make the machine heavier and to increase its cost.

On the motion of the Chairman, a cordial vote of thanks was accorded to Commander Gould.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

TUESDAY, MAY 29. University of London, at the Imperial College of Science, Royal School of Mines, South Kensington, S.W. 5.30 p.m. Dr. Edward M. Kindle, "Types of Sedimentation on the Atlantic Coast of N. America." (Lecture II).
At the Middlesex Hospital Medical School, Middlesex Street, W. 5.30 p.m. Dr. John Eason, "Graves' Disease." (Lecture I).

WEDNESDAY, MAY 30. Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m. Mr. F. Handley Page, "Slotted Wings." (Wilbur Wright Memorial Lecture).
University of London, at the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Dr. Hubert Hall, "Some common factors in the Economic and Social Development of England in Mediaeval and post-Mediaeval Times." (Lecture V).
At the Middlesex Hospital Medical School, Middlesex Street, W. 5.30 p.m. Dr. John Eason, "Graves' Disease." (Lecture II).

THURSDAY, MAY 31. University of London, at the Imperial College of Science, Royal School of Mines, South Kensington, S.W. 5.30 p.m. Dr. Edward M. Kindle, "Types of Sedimentation on the Atlantic Coast of N. America." (Lecture III).
At the Middlesex Hospital Medical School, Middlesex

Street, W. 5.30 p.m. Dr. John Eason, "Graves' Disease." (Lecture III).

At University College, Gower Street, W.C. 5.30 p.m. Prof. Max Bodenstein, "Chemical Kinetics." (Lecture I).

FRIDAY, JUNE 1. Philological Society, at University College, Gower Street, W.C. Paper by Mr. C. T. Onions.

Royal Institution, 21, Albemarle Street, W. 9 p.m. Mr. C. Leonard Woolley, "The Results of the further Excavations at Ur."

University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. Julian Krzyzanowski, "Polish Culture in the Middle Ages." (Lecture IV).

At King's College, Strand, W.C. 4 p.m. Monsieur L'Abbé H. Breuil, "Les Industries Préhistoriques par rapport à la Géologie."

5.30 p.m. Mr. R. G. Collingwood, "Roman Britain and Recent Excavations." (Lecture III).

5.30 p.m. The Hon. W. Pember Reeves, "The Philiké Etaireia and the Organisation of the Greek Revolt."

At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Mr. Philip Noel Baker, "The Treaty of Mutual Assistance and the Geneva Protocol."

At University College, Gower Street, W.C. 5.30 p.m. Prof. Max Bodenstein, "Chemical Kinetics." (Lecture II).

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICE.

NEXT WEEK.

FRIDAY, JUNE 8th, at 4.30 p.m. (Indian Section). S.C. STUART-WILLIAMS, Esq., Chairman, Calcutta Port Commissioners, "The Port of Calcutta and its Post-War Development," SIR CHARLES C. McLEOD, Bt., will preside.

Tea and Coffee will be served in the Library from 4 p.m.

PROCEEDINGS OF THE SOCIETY.

NINETEENTH ORDINARY MEETING.

WEDNESDAY, APRIL 25th 1928.

CAPT. SIR BEACHCROFT-TOWSE, V.C., K.C.V.O., C.B.E., Chairman of the National Institute for the Blind, in the chair.

The following paper was read:—

THE EDUCATION AND TRAINING OF THE BLIND.

By J. M. RITCHIE, M.A., Ph.D.

The education of the blind is a late development in modern civilization. Until one hundred and fifty years ago nothing was done. Before that time the average blind person was condemned to mendicancy and the blind individuals who rose to eminence were only the rare exceptions to this rule. The close association of blindness and beggary roused the sympathy of the philanthropic from the earliest days, and as far back as the fourth century we hear of the founding of asylums in which the blind might pass a peaceful if somewhat vegetative existence. The idea that the blind could be trained

to play a useful and self-respecting part in the life of the community was, as has been already said, a much more recent one. Its first missionary and pioneer was Valentin Haüy, a native of Picardy. The incident which first turned his attention to the needs of the blind has often been recounted. On one of the Paris Boulevards near a fashionable café, where the townsfolk thronged of an evening, a dozen blind men grotesquely attired and with paste-board spectacles on their noses, "were placed along a desk which sustained instruments of music, where they executed a discordant symphony and gave delight to their audience."

Haüy began his experiments with a single pupil, a boy whom he found begging at the door of a Paris Church, and in 1784 he opened the first school for the blind in the world's history, *L'Institution Nationale des Jeunes Aveugles*. In a couple of years he had thirty pupils in his school, but, unfortunately, the Institution had many vicissitudes during the remainder of its founder's life. Between 1830 and 1840 piano tuning was first introduced as a profession for the blind. From that time onwards the school specialised in training for this occupation to the exclusion of other handicrafts and gained a world-wide reputation in this field.

Haüy's example was quickly followed in other countries and in 1791 the first British School was opened at Liverpool. Before the end of the century three more had been established, and by 1850 another twenty had been added to the list. Although similar in character these Institutions were by no means identical. Some undertook the teaching of the young blind; some specialised in training for industrial occupations, some provided employment, while others afforded shelter to a number of the aged blind. Most of them included more than one of these sections within their walls. They were, of course, entirely dependent on charity, and it was not until well on in the nineteenth century that the first contributions from public funds were received. These were from Boards of Guardians, who had it within their power to contribute towards the industrial training of indigent blind people.

Attention may now with advantage be directed to a notable figure who from 1860 to 1890 played a leading part in the education of the blind. This was Thomas Rhodes Armitage who, being compelled at the age of thirty six to give up his medical career through failing eyesight, devoted all his energies and most of his private fortune to this branch of work. Only two of his many lines of activity can be noticed here, his missionary labours in the cause of Braille and his founding of the Royal Normal College. Dr. Armitage was impressed with the fact that only a few of the blind boys and girls who passed through the existing institutions were able to contribute substantially to their own livelihood when they went out into the world, and he set himself resolutely to bring about a better condition of affairs. He found matter for commendation in the Paris school in that many of its students obtained lucrative posts as Church organists and piano-

forte tuners, and along with young Francis Campbell, a blind music teacher from Boston, he established at Norwood a school which should improve on the record of the *Jeunes Aveugles* itself. The two principles on which he insisted above all others were, first, that great attention should be paid to gymnastic exercises and the care of the body generally, so that the students might suffer nothing from lack of physical fitness, and, second, that the best professors of music available should be employed. In Campbell, Armitage found one who by boundless energy and personal example was the very man for the task. He lived to become the doyen of the blind world. He was knighted in 1909 and died full of years and honours in 1914. The Royal Normal College not only bettered the record of the Paris school, but had a stimulating effect on all the other institutions of the country.

When the Education Act of 1870 was under consideration, an attempt was made to induce the Government to include the compulsory education of blind children among its provisions. A strong appeal was engineered by Miss Elizabeth Gilbert, the blind foundress of the great Institution in Tottenham Court Road, and an influential deputation waited on the Ministers in charge of the Bill. The effort failed, however, and it was not until 1890 and 1893 that the Education (Blind and Deaf Children) Acts became part of the law of the land. These statutes prescribed compulsory education for all blind children between the ages of five and sixteen years. Where the School Boards, afterwards the Local Authorities, did not provide and maintain schools of their own, they paid fees for the maintenance and tuition of the blind children of their own areas in the existing charitable institutions. These institutions came gradually under the jurisdiction of the Board of Education, under whose centralised control and vigorous admonition great strides were made. Premises were enlarged and improved, equipment and curriculum were modernised, and a certain degree of uniformity established.

The Education Act of 1902 decreed that public money should be spent on education "*other than elementary*," and in the course of a few years this phrase was liberally interpreted to cover those institutions and classes where training was given to blind students in preparation for a trade. The Act of 1918, now incorporated in the codifying enactment of 1921, carried the powers of Local Authorities still further and enabled them to pay maintenance allowances to pupils of any age who required specialised training on account of their disability.

Before leaving this historical aspect of the subject, it may be worth while noting the advent of two bodies expressly designed to promote the education of the blind. These were the *College of Teachers* and the *Association of Teachers of the Blind*, which were founded in 1907 and 1912 respectively. The College has since 1908 conducted examinations and granted diplomas to teachers in schools for the blind. The securing of this diploma is made a condition

of permanent recognition by the Board of Education. The Association was started, as has been said, in 1912, and soon became a professional body of considerable strength and influence. It is divided, for convenience of meeting, into three branches, and publishes a magazine called *The Teacher of the Blind*. The *College* and the *Association* were amalgamated in 1924. During the last twenty years the status and qualifications of the teacher have greatly improved. The proportion of certificated teachers has increased along with knowledge of the special methods applicable to blind children.

In addition to the distinction between schools maintained by Local Authorities and those charitable institutions governed by private committees, there is a further distinction to be drawn with regard to the type of school. Some are day schools, while some are residential. The old charitable institutions are mainly residential, while those established by Local Education Authorities are mainly day schools, although there are frequent exceptions to this rule. Where the fees charged by the institution include both tuition and maintenance, the whole amount is paid by the Local Authority, but as much of the charge for maintenance as is practicable can be recovered from the parent of the child. It is a pity that groups of Local Authorities have not exercised their option to combine for the purpose of establishing and maintaining residential schools. In the one or two instances where Local Authorities have done so they have set on foot hybrid establishments for both blind and deaf pupils. This is unfortunate, as there is little similarity between the educational problems presented by these two classes of children. One great advantage which such schools would have possessed would have been that as they catered for the blind of a wide area they would have been large enough to secure reasonably satisfactory grading of classes. This is a rather technical point, but it can be readily understood that if a number of children ranging from five to sixteen years of age has to be divided into four or five classes, the attainments of the pupils in each group are bound to be too varied to secure the best results from class teaching. A primary school for blind children should have a hundred and fifty on its roll before the grading can be considered satisfactory, and there is hardly one of this size in the country.

One of the standing controversies in the blind world is the comparative merits of boarding and day schools. No final answer is likely to be accepted, but it is probably safe to say that opinion is gradually consolidating on the side of the residential school. For the most part blind children come from poor homes, where environment and parental training are adverse to the best interests of the child. Even where the home is comfortable there is a tendency on the part of the parents to do too much for the blind child, to allow objectionable mannerisms to develop and to retard the formation of habits of self-reliance and independence. These are indispensable if the pupil : to grow into a self-respecting, self-supporting member of the community.

The out-of-school hours in a residential school can be turned to the greatest use for the wider purposes of education.

One objection sometimes urged against boarding schools is that the children are too much aloof from the needs and responsibilities of normal existence. When the criticism is justified, it is rather an indictment of the particular institution than a reasonable charge against the system. The teachers and other officers of a residential school must be ever on the watch to keep their pupils in constant touch with the everyday life of the larger world. They must take every chance of bringing their youngsters into friendly contact with ordinary children. They can meet as amicable rivals in competitions for music, dancing and handicrafts, and can share the common life of Scout and Guide Troops and of summer camps. They should go out frequently, not only for tramps and excursions, but to theatres, concerts and places of educational and historical interest. In such ways and in many more the atmosphere of segregation is broken down and the blind child is made a partner in the world at large.

At the present time there are about fifty day schools and about thirty residential schools for blind children in the country. The number of pupils is about 1,800 in the former and 1,500 in the latter. There are in addition two secondary schools, one for boys and one for girls, with about seventy pupils at present in attendance. With the lapse of time the opinion has gained ground that the sooner a blind child can be brought under specialised care and supervision the better for his future well-being. Three nursery schools are now looking after more than sixty children under the age of five. All, or nearly all of these little ones come from homes whose circumstances are undesirable.

About three hundred teachers are engaged in the work. The curriculum and educational method follow as closely as is practicable those of a school for normal children. One or two subjects, such as drawing and painting, have to be omitted, but the rest of the teaching is pursued on lines analogous to those of the ordinary school. Normality is one of the aims which the teachers must keep resolutely before themselves. They must never forget that they are preparing their pupils for life in a five sensed world. The children must be taught to bear themselves intelligently towards an environment of which they cannot have a complete range of first hand concepts. They must be taught to listen with some show of understanding, to talk about colours, scenery and the like, although these can make to them no direct appeal. At the same time, even while this conventional instruction is going forward, the teacher must remember that education to be real and vital must be first hand. He must, therefore, study to train his pupils by the senses of hearing and of touch. These two lines of thought are divergent, but they must both be utilised if the training given is to be satisfactory and complete.

After what has been said, it will not be surprising to hear that a visitor

who goes round a blind school for the first time is usually struck by the closeness of its resemblance to a school for seeing children. The usual school terms are kept, and the pupils return home for holidays at Easter, Summer and Christmas. The youngsters are bright and happy, and everything is done to make the most of these ten critical formative years. The function of the school is to shape and strengthen character as well as to develop intelligence. Its purpose is to assist both boys and girls, according to their different needs, to fit themselves practically and intellectually for the business of life. A heavy responsibility is laid upon the teachers who are called to this special work. They must endeavour by example and influence to implant in the children habits of industry, self-control and courageous perseverance in the face of difficulties. They must foster in them a strong sense of duty and promote that consideration and respect for others which is the foundation of unselfishness. They must inspire that corporate life of the school which makes for the development of an instinct for fair play. Thus is encouraged loyalty to one another, which is the germ of a wider sense of honour in after life. The handicap of blindness has to be minimised and overcome.

It is a difficult task, and people unacquainted with the blind often fail to realise the infinite patience and application required for success. Frequently, as has already been suggested, when the little boy or girl is first admitted he has been spoiled by misdirected kindness. Everything has been done for him, with the result that he is totally unable to do the simplest duties for himself. Two actual cases of this may be cited by way of illustration. A boy of fourteen when first brought to school was found to have spent his whole life in bed. His grandmother who had charge of him thought that this was the best and surest way of avoiding the many dangers of an active existence. He put on two stones weight in the first six weeks of his stay at school and became a sturdy lad, but, of course, the years that he had lost were so many opportunities for education and social training that had gone for ever.

The second instance is that of a boy of eleven who, as a result of similar over anxiety on the part of the parent, had never been allowed to walk. When brought to school he looked hopelessly paralysed, yet no trace of organic disease could be found, and in a fortnight he could find his own way along corridors and up stairs. It will readily be gathered from such extreme examples that even in the average case social training in the most elementary details forms no inconsiderable part of the curriculum of the younger classes.

The medium for reading and writing is Braille, a system of embossing which can be interpreted by touch. It was invented in 1829 by Louis Braille, a blind teacher in the *National Institution for Blind Children* of Paris. It has been adapted to meet the needs of every civilised language of the globe and has proved one of the greatest boons ever put at the service of the blind. By its means a clever blind child can read and write as fluently and accurately as a seeing child of the same age. Thus history, literature, composition, etc., can

all be carried on with little change in the methods that would be employed in an ordinary school. The Braille system is of such importance that a fuller description may not be out of place. Valentin Haüy adopted for the use of the blind a system of reading in large italic embossed letters. His example was followed by many other experimenters, and for more than half a century several competing forms of Roman letter held the field. These systems, although attractive to the eye, were difficult to read by the finger and no great fluency was ever attained. Braille's system, on the other hand, was arbitrary, i.e., it had no resemblance to the written or printed letter used by sighted people. The foundation of the system is a group of six dots of which sixty-three combinations can be made. The dot is more easily felt than the line, and, as has already been indicated, a high degree of facility in reading can be reached. The system has also this great advantage, that it can be written with ease. It may be noted in passing that written is identical with printed Braille. Orthodox opinion in the early nineteenth century held that the best type for the blind was that which was legible to the eye as well as to the finger, and so it was not until Braille's system had been in existence for more than twenty years that it was adopted by the Paris School. Mention has already been made of Armitage's labours in the popularising of Braille in this country. Recognising the strength and permanence of an organisation as compared with an individual, he founded, in 1868, *The British and Foreign Blind Association*. This became in 1914 *The National Institute for the Blind*, of which Sir Beechcroft Towse is to-day the honoured Chairman. Armitage gathered round him a group of able blind men, considered carefully the claims of the various types and decided in favour of Braille. Thereafter he pleaded in season and out of season for its adoption by the schools not only of this country but of the world, for he travelled in Europe and America on the same crusade. It is interesting to recall that one of the first steps he took in this direction was to lecture on its advantages in this very room sixty years ago. His zeal and devotion had their effect, and between 1880 and 1890 Braille became the universal medium for education. Besides the original adaptation to the English language the Braille system was carefully revised in 1905, and the modification then established has now reached the proud distinction of being the recognised medium in all English-speaking countries.

Braille is, of course, much more bulky than letterpress. The pages must not be squeezed tightly together and, therefore, the books although huge, are comparatively light. The novel *Henry Esmond* occupies six volumes, while *Martin Chuzzlewit* occupies twelve and *Bleak House* fourteen.

There is a considerable body of literature available for the blind reader, and the *National Library for the Blind* alone has over a hundred thousand volumes. Many of the Library's books are handwritten, but a substantial amount of printed Braille is turned out by the National Institute in London and the Royal School for the Blind in Edinburgh.

Another piece of special apparatus makes it possible for arithmetical problems of every kind to be worked without the aid of the eye. This appliance was invented by the Rev. William Taylor nearly sixty years ago, and in spite of its shortcomings has not yet been superseded. It consists of a board full of octagonal holes into which square pegs can be placed. The pegs are all alike with a bar at one end and two points at the other. The eight positions in which the peg can be used give the first eight digits, while the other end of the peg in similar positions gives the remaining digits and six algebraic signs.

Embossed globes and maps make geography a possible though difficult subject of instruction.

So much, it may be said, for machinery and mechanical apparatus. What about the mentality of the blind child? What are the psychological bases for his instruction? That is a large question and only fragmentary indications can be thrown out here. First of all, the problem is complicated by the fact that less than half the children in blind schools are totally blind. Blind, according to the definition of the Board of Education means, "too blind to be able to read the ordinary school books used by children." The mental processes of a child with partial vision or of one who has lost his sight after the age of five may be taken as normal, and so, although they complicate the teacher's task, they may, for the moment, be neglected. A child who has been totally blind from birth or infancy is in another category. The one great primary difference between him and his fellows is that visual imagery as well as sight is denied. The man who possesses the power of seeing has also the power of storing up images, memories of things seen, of recollecting these at will and of forming from them new pictures. He can recombine the elements of line, and colour in infinite permutation. He can construct in the mind a lively presentation of tropic forest or Antarctic waste without ever having been outside his native shores. All that is done in such mental exercises is to arrange familiar elements in unfamiliar combinations.

The case of a man who from early years has been incapable of the sensation of sight through defect in optic apparatus or in brain is very different. Unless the sense mechanism is there and can be set in motion by the appropriate stimulus no real impression can be conveyed to the mind. "The mind," says Locke, "can frame unto itself no one new simple idea." "No mental copy can arise in the mind, or any kind of sensation which has never been directly excited from without. The blind may dream of sights for years after they have lost their vision, but the man born blind can never have a mental vision" (William James).

In the daily life of the ordinary human being it is difficult to exaggerate the part played by sight and its concomitant visual imagery. Many years ago Galton made experiments which showed that the degree of vividness of this imagery varied greatly in different individuals, but even those with feeble powers of visualisation depend upon the sense of sight to an enormous extent.

It is not too much to say that most people regard life from the standpoint of vision. Their world, whether seen or remembered, is a realm of shapes and colours. Rumination upon even a concert or a dinner is visual. From the recollected scene are abstracted by intellectual process sensations of sound or taste. In other words, not only does the ordinary man discern objects by sight and remember them by visual memory, but everything that claims his attention is seen or remembered upon an everpresent visualised background.

Instead of sight and pictorial memory the blind have muscular and tactual sensations and images. To the average man tactual images can be little more than a phrase. Any image of this sort which he may form is at once jostled out of the focus of attention by the overwhelmingly vivid pictorial representation. The blind man's images are always tri-dimensional; the ordinary man's are seen and remembered upon a plane background and must be overridden and corrected by his knowledge of the third dimension.

Enough has perhaps been said to sketch in rough outline this initial difference between the mind of a man born blind and that of a normal citizen. Such a condition naturally gives rise to secondary effects which ramify in many directions.

At the same time, the warning must be expressed that generalisations are dangerous. Temperament is more fundamental than blindness. The common statement, for instance, that blind people are introspective could be more accurately stated. Blind people are merely a fortuitous cut from the general population, and, therefore, will include roughly the same proportion of introverts and extroverts. All the same, it is patent that the effect of blindness will be to drive a man in upon himself and so aggravate introspection. Facts like these present problems of intense interest to the enthusiastic teacher, but time forbids more detailed treatment here. Only one other secondary effect of blindness will be touched on, and this, not because of its intrinsic importance, but because of its wider application. It may be regarded as a short digression on the topic known as "defence mechanism." This is a curious compensatory device whose action may be noted in many places, not all of which are situated in the country of the blind. It is a common weakness of many blind people to indulge unduly in big words, both in speaking and writing. The modern cult of the conversational in style leaves them cold. They roll the polysyllabic phrase lovingly round the tongue and quickly respond to like eloquence in others. That such a trait is allowed to persist after school days is a reflection on the current teaching of English, for the misuse of words is, in most, an eradicable failing, but the real point at issue is that to a degree distinctly greater than among their seeing comrades, blind adolescents and adults have a tendency towards this weakness.

Now for the digression. The designation "defence mechanism" is less familiar than the facts themselves, which can be observed in many homely and familiar situations. Human beings prefer the pleasant to the unpleasant.

They therefore try to avoid the unpleasant, and in this endeavour their subliminal consciousness comes to their aid. Scrupulous people would be pained if they realised the tricks their mental underworld thus plays upon them. Subconsciousness sees to it that disagreeable appointments are forgotten and troublesome tasks slip the memory. Further, if a course of conduct has been reprehensible, the unconscious mind invents spurious justifications and allays any uncomfortable feelings that would otherwise result. Bernard Shaw was aware of this little weakness long before the psycho-analysts had given it a classification and a name. "When an Englishman," says the man of Destiny, "wants a thing he never tells himself that he wants it. He waits patiently till there comes into his mind, no one knows how, a burning conviction that it is his moral and religious duty to conquer those who have got the thing he wants . . . You will never find an Englishman in the wrong. He does everything on principle. . . . His watchword is duty and he never forgets that the nation which lets its duty get on the opposite side to its interest is lost." At a still earlier period another writer illustrated an excellent instance of defence mechanism by a story about a fox and grapes that were sour. The undersized man not infrequently carries himself with more than ordinary self-assurance, and is of an unalterable conviction that it is quality and not quantity that counts. Can the verbal exuberance of the blind man be fitted into any such category? Can we not trace in this mental phase a revolt against the galling conviction of his inferiority? His subconscious mind sets about redressing the balance. If he is handicapped in regard to vision, there are other regions of activity in which no disability exists. The use of words is one of these, and he strives by an exaggeration of literary language to show his superiority to the average man. For the same reason he makes much of the mistakes that seeing people commit. "Just the silly sort of thing a sighted man would do!" he says, and smiles complacently at the immunity of himself and his friends from such blunders.

Reference has already been made to the fruitful example of the Royal Normal College on the physical development of the blind. In every school special attention is now paid to this indispensable preliminary to all other aspects of education. The reason why this is necessary is not far to seek. The restless activity, the constant movement and the strenuous exertion which are characteristic of all healthy young animals, and which are necessary factors in normal growth and development, are lacking in the blind. Blind children, if left to themselves, do not take wholesome exercise and are usually found to be below the average in physique and vitality. The business of counteracting this disabling effect of blindness can best be carried out in a residential school. Remedial exercises for those who suffer from structural and postural defects, drill, gymnastics, dancing and organised games play an important part in the curriculum and time-table. By such means the pupils are lifted from lethargy and weakness

and are transformed into stalwart, energetic youngsters with upright carriage, easy movement and fearless gait. In this connection, it may be mentioned that teams of blind children have entered into Folk Dancing competitions and have won a high place among seeing competitors. In the English Folk Dance Society's Festival held at the Albert Hall a year ago a blind team took part. The successes gained by the blind boys at Worcester College in rowing against well-known eights and fours may also be recalled.

A blind pupil comes to the end of his primary education at the age of sixteen, but two or three years before that time his teachers have been trying to discover the line of work for which he is best suited. From the infant classroom upwards he has been taught to use his hands first in social activities, such as dressing, table laying, etc., with Montessori apparatus and later with simple handicrafts. By the age of thirteen or fourteen it will have been evident to his teacher whether he can hope to take up music as a profession or whether he must rest content with basket making or one of the other occupations usually followed in workshops for the blind. During his last few years in the primary school his handwork curriculum will, therefore, have been modified in accordance with his probable future needs.

A guiding principle in the welfare of the blind in Great Britain is continuity of care and supervision. Most of the large residential schools have departments which carry the pupils to the age of twenty and provide courses of training in all the better-known occupations. At the present time there are about 1,300 students in attendance at these courses. Girls are taught machine-knitting, hand-loom weaving, light basketry, shorthand and typewriting, telephony and music, while boys follow courses in music, pianoforte tuning and repairing, basket-making, boot-repairing, mat-making, brush-making and, in a few instances, massage, telephony and typewriting. Those pupils who show strong scholastic abilities may be transferred to the secondary schools, and after several years' study they can pass on to the University and enter the professions of teaching, the law or the Church.

Behind these few sentences can be detected a profound difference in the problems which face the school for blind and the school for seeing children. Hardly any ordinary school sets out with the professed aim of training its pupils for this or that definite occupation. Its ideal is to develop and strengthen the character and powers of its pupils in an all round manner. Specialisation is not its province. On the other hand, a school for blind children has to prepare its pupils for the trade at which it is hoped they will afterwards make their living. It has thus to combine as best it can the ideals of a liberal education and efficient technical training. The fact that the pupils, for the most part, remain at school from five to twenty years of age puts in the hands of the teachers a powerful instrument for real success in this direction. The lads and girls who are having their technical training also attend classes in English, economics, drill, singing and such like cultural subjects. In other words, the

educational atmosphere is continued right up to the stage at which wage earning begins.

Another class of pupil must be mentioned. Owing to disease and accident many people become blind in adult life, and for these, too, provision is made. Under the Blind Persons' Act of 1920 and the Education Act of 1921 it is the duty of the community to see that such disabled men and women are given full opportunity of joining once again the ranks of self-supporting citizens.

The principle of continuity above referred to again comes into force at the close of technical training, and specialised workshops for blind operatives are established and maintained all over the country. These are carried on under the central supervision of the Ministry of Health, and grants are paid to the Institutions conducting such workshops. This is no part of education, but the various stages of the problem of how to deal most effectively with the blind population are so closely knit together that reference to the later sections of the programme cannot altogether be omitted.

The old days of unaided philanthropy have passed away. The conscience of the community has responded magnificently to the call of the blind, so that to-day there is appropriate machinery at hand for assistance in every stage of life. At the same time, blindness is a severe disability and even with all the help, both State and charitable, both paid and voluntary, that is ready to be placed at his disposal, the blind citizen who makes good is one of whom his country should be proud. He who overcomes such a heavy handicap has helped to raise the stature of humanity and has contributed living evidence to the dominance of mind over matter. Particularly hard is the lot of the man who goes blind in middle life. Henley's well-known stanzas too often ring flat with a certain forced air of bravado. They lack a sense of proportion and remind one of the childish attitude of Ajax defying the lightning. All the same, if anyone can lay claim to turn them to his own use, it is surely he who, having known the light, has disciplined himself to walk with fortitude the unseen road before him. Such an one who, in manly cheerfulness, can keep his heart warm and his muscles taut, is entitled to repeat in unaffected honesty :

" Out of the Night that covers me,
Black as the pitch from Pole to Pole,
I thank whatever gods there be
For my unconquerable soul."

DISCUSSION.

THE CHAIRMAN, in opening the discussion, said he had been particularly interested by the lecturer's remark that in the olden days the blind were dependent on beggary, because the National Institute for the Blind, and others who were working in the cause of the blind, were especially desirous of uplifting the blind so that they should be able to earn their living and support themselves and their families, which, as Dr. Ritchie had said, in his experience could easily be done if sufficient help

was given. Another point made by Dr. Ritchie was that the curriculum in blind schools was much the same as the curriculum in sighted schools. Personally he was very sorry to hear that that was so. He thought the curriculum in the sighted schools was rotten. Perhaps he ought not to say this, in view of the many millions that were spent on the education of the masses, but he had good reasons for his opinion. During the war he was in France helping the wounded men, and he had written hundreds of letters for the Tommies, for Englishmen, Irishmen, Scotsmen, New Zealanders, South Africans, Australians, Newfoundlanders, and men from all over the Empire. From England, in reply to many thousands of letters, he had received about $4\frac{1}{2}$ per cent. of answers from the parents; from Wales a little less; from Ireland about 3 per cent; while from the Colonies,—Australia, New Zealand, Newfoundland, South Africa, Rhodesia,—he had received 97 per cent. of answers. The letters from England, Ireland, Scotland and Wales were hardly decipherable, their composition was deplorable, and in fact they were dreadful productions. Those from the Colonies were absolutely masterpieces, not only of gratitude, but they were well-written and well-composed. Yet the Colonies spent nothing like so much as we did on the education of their children; indeed, in many cases, the children could not attend schools, because they were hundreds of miles away from any school. What was the ordinary curriculum worth, and what was Dr. Ritchie's curriculum in the blind schools, worth?

He disagreed with Dr. Ritchie in regard to the mentality of the blind. He presumed that the mentality of the blind children was, or ought to be, the same as that of sighted children; but no doubt there were more learned people present who could tell him why it should not be. If people became blind in after life, it did not follow that their mentality was any the worse. It did not follow because a man had lost his sense of sight that he had lost his brain. As far as his own observation went, he had found as many stupid people with sight as without sight. The sighted people had not a monopoly of brains. Sighted people did not always treat the blind properly; they would take a blind man by the arm and push him into every danger that was about. If they used their own sense, they would let the blind person take the sighted person's arm. Sometimes a sighted person told him, for instance, that there was a chair in front of him, whereas if only his hand were put on the back of the chair he could get into it as quickly as any sighted person. When he had returned to London after being wounded, he had amused himself, knowing London fairly well, by trying to be independent. He used to get into a hansom cab at Paddington station and tell the cabman to drive somewhere, and he also used to tell him not to get down from his box, but to wait outside the shops, and if he had to move away from the shop door, to call out when his fare came out of the shop. But he was never allowed to get into the cab by himself; everybody used to rush at him, and attempt to help him; and sometimes, when he took off his hat and said "Thank you," he felt more like saying "Go to——!" That was the fault of the other man, not his own.

What the National Institute for the Blind wanted to do was to bring people up and educate them to be self-supporting, self-respecting citizens, and to relieve the blind people from being a burden to themselves and a burden to the State. This could be done if it was done properly. It was being done in Germany and in other countries, but not in England. No one was happy without work, and it was not enough to teach the blind to make baskets and mats, which Japan could do at far less cost. The blind should take a hand in business and in trade. That could be done if instruments were made safe.

MR. JOHN FRANCIS CUNNINGHAM, F.R.C.S., said he had been greatly interested in the lecture. He had been forbidden to speak about the Chairman's war-time services, and he had nothing else to contribute to the discussion, having come to sit at Dr Ritchie's feet and learn what he had to teach.

MR. BEN PURSE, said he also had listened with intense interest to the lecture delivered by Dr Ritchie. He felt certain that had he been able to give the whole of his paper, all those present would, like himself, have been very enthusiastic about some of the passages which lack of time had forced him to omit. The psychological aspect of blindness was one which, within recent years, had attracted and was attracting a very great amount of concentrated attention. Those who knew most about the subject were not yet able, and not yet willing, to dogmatise, but Dr. Ritchie, in several ways, had made exceedingly useful contributions to the subject. He hoped it might be the privilege of that audience upon some future occasion to have Dr. Ritchie's attention devoted entirely to a lecture on the psychology of the blind.

He entirely agreed with the lecturer's observations as to the curriculum. He thought it was essentially a good thing that the curriculum at the disposal of the blind children should be as nearly allied as possible to that provided for the education, training and guidance of sighted children. He did not regard the present expenditure on education as a colossal piece of stupidity; on the contrary, he thought it was money wisely spent, and his only quarrel was that insufficient money was being spent on education in the right direction. He was not so sure that he would be disposed to consider the observations of the Chairman as being in the right direction. However that might be, he was quite convinced that they had all spent a very useful evening in listening to Dr. Ritchie's able lecture. He was certain that in the literature at the disposal of those interested in work on behalf of the blind, the lecture would take a useful place, and would be regarded in future as a very practical contribution to that literature.

DR. P. M. EVANS, who also expressed his gratitude to the lecturer, said the address had shown how, step by step from many years back, endeavours had been made to train the blind from infancy to manhood, so as to enable them, in spite of the curriculum upon which the Chairman had somewhat reflected, to become self-supporting, or partially self-supporting, and self-respecting citizens. Enormous strides had been made in that direction since the Act of 1920. He did not think the lecturer had referred to the steps which were being taken to ensure that the people who were engaged in educating the blind were themselves well educated and fitted for the task. Dr. Ritchie was a very prominent member of the College of Teachers, and in their examinations every endeavour was made to ensure that teachers who were seeking engagements in that very arduous and important work were thoroughly up to the task which was set before them.

All the efforts that were at present being made were in the direction which had been pointed out by the Chairman, i.e., to enable the blind to take their position in the sighted world in the ordinary way. Improved schemes of home visiting and after care were in operation; and efforts were now being made by the National Institute for the Blind to widen the scope of employment of blind persons. If the work of the Committee at present sitting on that work was successful, new avenues of employment should be opened up, and the point to which the Chairman had referred would gradually be reached. In those efforts he was sure the support of the Chairman, and of everybody who was interested in the welfare of the blind, could be relied upon.

MR. J. CLYDESDALE, (National League of the Blind), said he had been very much struck by the omission from the lecture of what might have been expected to be a natural conclusion, namely the results of blind education. Compulsory education for the blind had been in existence since 1891 or 1892, and training for the blind for a considerable part of that period. There had also been a good deal of secondary education for the blind, and the strange thing was that as the result scarcely one of the important positions in any of the great institutions for the blind was held by a blind person. That seemed to be an indictment to some extent, or at any rate, something which required explanation, of the results of education for the blind. The National Institute did not seem to find as many jobs for blind people in their higher spheres as they used to do. There was a gradual tendency to forget the blind man in his own work, and a tendency to develop a profession of sighted people to look after the blind. Of course, some sighted assistance was needed, but there was a certain amount of initiative coming from the intelligent and capable blind man which could be carried forward probably to the advantage of the blind community among which he worked. That initiative, which could only be got from somebody with experience of blindness, was frequently denied an opportunity, and the opportunity was conserved for a new sighted profession gradually growing up all over the country. There was an enormous increase in the numbers of sighted officials looking after the blind, and no evidence of a recognition of that eminent ability among the blind which some men had, and which could find expression if given a chance. He had therefore come to the conclusion which he had already stated, and he thought a good deal of Dr. Ritchie's analysis and historical record was very valuable, but did not go quite far enough. The real problem and the real difficulties of the blind were not touched. One might discuss psychology, but the Chairman was right—a normal blind man, a man with all his physical fitness, was simply a man less his sight, and it ought not to be a very difficult thing to measure his psychology. Too much exaggeration was put upon blind psychology. There was a special blind psychology due to blindness in infancy, and he thought the lecturer would agree with him and the Chairman that blindness in infancy was a decreasing quantity. Medical science was gradually eliminating it, and the time could be looked forward to when even blindness in early youth might be limited. He had come to hear the lecture definitely with the purpose of hearing what Dr. Ritchie was going to do with the blind educated man, so that he should not be crowded out of a sphere of usefulness for which he was fitted, by confining the posts almost entirely to sighted people. At present, there was scarcely a chance of a blind teacher getting employment in a school for the blind. There was scarcely any chance of a blind man or woman getting employment as a home teacher, while their experience as blind people would be very valuable in hundreds of cases. He hoped this comment would receive the attention of the lecturer.

THE CHAIRMAN, in reply to the last speaker, said it was true that in schools the blind always looked to sighted people to instruct them. That might be right or wrong, but the previous speaker was a little wrong in saying that the National Institute for the Blind was not finding posts for educated blind people. Of late years he had found a good many positions, and he was finding a good many posts at the present time for blind educated people. When he said educated people, he meant people who had passed their examinations and made good. He had set up people in massage, men who were privates and also able-bodied seamen, in the war. One man was now a lawyer, having passed his examinations. If the

blind people made good, posts could be found for them ; but as to instructing them, there were not many blind instructors. The policy was to help the blind to help themselves.

MR. W. P. MERRICK suggested that the education of the blind should take as practical a form as possible. A few years ago in Sweden he visited the school at Tomtebodå, where the blind girls were taught cooking. The ordinary mother would say her child must not touch the stove, because she would burn her fingers, but those girls made good cooks, and did everything in the house. He asked the matron whether the intention was that the girls should earn their living by it, and found that this was not the only object. Every woman might have to keep house for herself, and if she could do so for her family, she liberated her sisters for work in the fields or in the town. He wished to make a very strong plea that the education of blind boys and girls should fit them in every possible way to look after their own homes. Blind boys should know as much of carpentry as possible, and be able to do little things about the house, even cook, rashers and eggs, and all such things.

With regard to the intelligence of blind people, he wished to remind those present that every single service in existence had been instituted by blind persons. Edward Rushton, who started the Liverpool School for the Blind, was blind and so were Miss Gilbert, Dr. Armitage, and the two boys in France who, after getting a thrashing for smashing the old school piano, instituted the practice of piano tuning for the blind, which had since proved to be their best means of earning their livelihood.

DR. RITCHIE, in reply, thanked his audience for their patient hearing. The precise scope of the subject with which he had dealt had been given to him, and many things had had to be left unsaid. Therefore, while he was more conscious than Mr. Clydesdale could be of the shortcomings of his lecture, he did not think it was a fair criticism to complain that it was not a lecture on the employment of the blind. Also, being a paper on education, he was sorry not to have been able to spend more time on the psychological aspects of the subject, which were both intensely interesting and much more difficult than Mr. Clydesdale seemed prepared to admit.

He agreed with a good deal of what Mr. Clydesdale had said, and he thought if they had a quiet evening together, they would find that they were really of one mind upon many points. Some of the best teachers he had known had been blind, and he personally would be sorry to think that the day was approaching when there would be any diminution in the number of blind teachers in the schools. The more posts of responsibility and administration they could secure, the better it would be for the blind work as a whole.

He was very glad that Mr. Merrick had pointed out—he had intended otherwise to have done so himself—that most of the pioneers he had mentioned in his historical sketch were themselves blind people.

On the motion of the Chairman, a hearty vote of thanks was accorded to Dr. Ritchie for his lecture.

CORRESPONDENCE.

CO-PARTNERSHIP IN INDUSTRY.

Mr. Archibald Crawford, in his very interesting paper on "Industry Fifty Years Hence," has ignored one element which is not only a possible cause of unrest, but may also be a serious obstacle in the way of co-partnership and other similar developments. I refer to the ever-increasing use of "loan" capital, with mortgage or prior rights to the profits, and even to the property of a business. This element should not be confused with "working capital," truly so-called, and yet it is constantly so confused. An industrial partnership is a natural arrangement between "capital" normally invested in industry, and labour, since each nowadays recognises the other as a necessary associate, equally risking and, more or less, equally gaining or losing. And as long as industry is carried on by these two elements, equality of effort and risk invoke sympathy and understanding. But when the moneylender (politely called a "bondholder" or "debenture" holder) intervenes there is no longer that community of interests; the business becomes a triangular contest, a game of "cut-throat" in which the moneylender holds all the cards. And he, the moneylender, toils not, neither does he spin; he sits and collects his fixed interest, or in the last resort he forecloses and demands his pound of flesh. It would appear that in these conditions no "partnership" is possible between the two other elements, and it is unfortunate that the word "capital" should be used to describe the employment of money in two such radically different ways. Business men understand the true significance of "loan capital," but it is not easy for the worker to appreciate why a large percentage of what should be the profit of a business, after paying all working costs, should go in what are euphemistically described as "fixed charges." It is true that some fortunate businesses do not require loan capital, but they are few, and it is unfortunately increasingly the custom now to commence a business, regardless of ethics, with a proportion of loan capital in addition to the share capital; in other words to start in debt. The most extraordinary thing is that in all the discussions on this vital question no reference should ever be made to the all-important element of loan capital, and the influence of the moneylender. The City of London is far more highly organised, politically and otherwise, than the men's trades unions, and any forecast of conditions fifty years hence must take account of whether the moneylender is going to extend his influence, already almost universal. Obviously, there can be no opprobrium attached to this form of "moneylending," and I have used the term only to drive home the distinction.

GEORGE L. BOAG.

NOTES ON BOOKS.

THE PRACTICAL BOOK OF ITALIAN, SPANISH, AND PORTUGUESE FURNITURE. By H. D. Everlein and R. W. Ramsdell. J. B. Lippincott Co., Philadelphia & London. 42s.

Messrs. Everlein and Ramsdell write very lucidly on furniture. They are explicit about sources of inspiration, development and technique. Their illustrations leave nothing to be desired. In this book they begin by explaining the gradualness with which Renaissance motives displaced or transformed Gothic, saying enough at the same time to give a reader ignorant of social history some idea

of the domestic conditions obtaining in the fourteenth century, when the change from the middle ages to the modern period was taking place.

Italy was at this date in advance of the rest of Europe from the cultural point of view. Even so, the common chair had not yet a place in the houses of the great majority of people, and not a very secure one except in the mansions of the rich and powerful. The masses had to be content with stools and benches. Generals and important persons, indeed, had in addition to chairs at home the folding wooden *sedie del campo*, forerunners of our camp-stools, which are only their degenerate posterity. Nor were beds as plentiful as in these days of cheap iron frames we might be deceived into thinking they must have been for a thousand years. The *cassone*, or chest, played an important part in those days, not dissimilar to that of our "divans." Only these chests, convenient beds by night and sofas by day, were primarily a receptacle for storing clothes and goods of all sorts. *Cassoni*, stools, sideboards were ornamented in a large variety of ways; with carvings, mouldings, metal bands and inlay of wood (*intarsia*) or of ivory (*certosina*).

The tendency in Italy was to construct furniture on horizontal lines, both the main design and the detail being kept architectural in character. Naturally enough, as "early" Renaissance developed into "high" Renaissance, detail became more refined; and as the "late" Renaissance turned Baroque, the refinement was carried further, occasionally to grotesque extremes, while comfort was more and more studied by makers of furniture.

Spanish work in the sixteenth century was altogether less architectural than Italian in its main outlines, and as a result of Moorish influences detail was geometrical rather than naturalistic. The keynote of Spanish interior decoration was strength and dignity, the geometrical detail being of great intricacy. The most distinctively Spanish piece of furniture was the *vargueño*, a cabinet, again of Moorish antecedents, and the progenitor of the falling-front *secrétaire*, therefore a matter of international importance. The early *vargueño* was quite small: a portable rectangular box with one side hinged at the bottom, and inside, a number of sliding drawers or pigeon-holes. The later and larger *vargueño* would be kept on a special stand; ultimately the two were built as one.

Portugal was far from being a negligible factor in the evolution of furniture. Already at an early period her sailors and merchants had introduced oriental ideas from the eastern colonies, and from Portugal these spread to Spain, France and England. Examples are the caning of chairs and the spiral twist, which seems to have come to the United Kingdom in the train of Katharine of Braganza, who, according to John Evelyn, "brought over with her such Indian cabinets as had never been seen before."

P.B.

NATURAL RESOURCES OF THE NETHERLANDS EAST INDIES.

In his recent report on the Economic Situation of the Netherlands East Indies, the British Commercial Agent at Batavia gives the following particulars regarding certain of the natural resources of these islands:—

China Clay Deposits.—The question of the local manufacture of cheap china-ware for sale to the native population has for some time past been given considerable attention by the officials of the Division of Industry at Buitenzorg, who are prepared to grant any one disposed to put capital into such a venture all the information at their command and any technical assistance available. The principal requirement for the profitable working of a pottery industry is an adequate supply of a suitable raw material. Kaolin has been found in commercially exploitable quantities near Trenggalek, in the Kediri residency of Java, for which the concession rights are

held by a Dutch subject. Engineers of the mining service have recently been engaged in prospecting for further china clay deposits, and it is now announced that suitable material has been located in the Island of Madoera and in yet another area in Kediri.

Coal and Silver in Bantam.—During the period of the late war the mining service carried on an intensive investigation into the whereabouts of coal deposits in Java. In the Bantam district, West Java, a good variety of coal was found, also lignite deposits of a useful quality. Exploitation was, however, never begun owing to the lack of roads and transport facilities. The Government, it is reported, is now planning the extension of the system of roadways in Bantam, which extension will include the coal areas discovered on the south coast and near Bodjong Manik in this residency, so that a Government coal mining industry may be established in Bantam in the not very distant future.

Marble Deposits Discovered.—During the activities of the Forest Department in the mountain areas in the Klaten and Imogiri districts, Mid Java, traces of natural deposits of marble were discovered in four places. The marble is said to be of fine quality and beautifully tinted with red, green, orange and other hues. Samples have been sent to the Department of Agriculture, Industry and Commerce at Buitenzorg. An investigation will be made to ascertain the possibilities of commercial exploitation of these deposits.

AGRICULTURE IN PERU.

Peru is essentially an agricultural country, and upon the development of agriculture the prosperity of the country mainly depends. It is true that the mineral and petroleum wealth is almost as important a factor in the national perspective, but control of these industries has been allowed to pass almost entirely into foreign hands, with a result that the country derives no benefit from their operation other than the salaries and wages paid, since the minerals extracted are disposed of abroad and the profits also distributed there. Agriculture, on the other hand, is almost exclusively in native hands; it employs by far the largest number of people of any industry, and it represents by far the largest national investment. The total farm lands in Peru amount to 3 million acres, of which 1 million acres are along the coastal zone, and the remainder in the Andean and Trans-Andean region. There are estimated to be £p.63,000,000 invested in agriculture in Peru, exclusive of livestock, of which 60 per cent. has been placed in the irrigated districts of the coast. The principal products in the order of their importance are cotton, sugar, wheat, rice, potatoes, maize, barley, alfalfa, tobacco, coffee and coca, in addition to fruits of all kinds, such as bananas, oranges, grapes, olives, alligator pears, custard apples and mangoes. In spite of the importance of agriculture, however, it is not sufficiently realized, says H.M. Consul at Callas in his recent annual Report, that it should be the first concern of an agricultural country to provide adequate sustenance for its population, as it involves the whole question of the cost of living; as a result, half of the food crops required for local consumption have to be imported into Peru, while cotton fields are suffered to extend right up to the very confines of Lima. Capital and science appear to have been concentrated on the production of cotton and sugar cane, on account of their larger value as export commodities, while market gardening and other food production have been neglected; the result is that food, not being produced near at hand, and having either to be conveyed at great expense from the interior or else imported, is always scarce and very costly in the large consuming centres. This leads to high money wages, and these have to be added to the cost of production of the non-alimentary crops which are grown for

export. More mixed farming, greater rotation of crops, and less concentration on specialized products is the solution for agriculture in Peru in order to rest the soil and preserve a more equitable balance of production. The concentration on exportable production is largely the cause of the present economic depression, owing to the drop in cotton and sugar values. Severe impoverishment of the soil has resulted, necessitating the constant application of guano fertilizer at great expense. Cost of production could be lowered by the more general use of machinery, and the introduction of more efficient methods of cultivation.

MOTOR TRAFFIC IN FINLAND.

H.M. Consul General at Helsingfors calls attention to the extraordinary rapidity with which motor traffic continues to develop in Finland in spite of the generally unfavourable condition of the roads in that country. There is hardly any part of Finland that one can visit without seeing the motor car or motor lorry in use, but the absence of the British car in the market is, unfortunately, conspicuous. On the other hand, the market is well supplied with American cars, while a number of French and Italian cars also find a sale in this country.

There are about 11,000 motor cars and well over 5,000 lorries and buses at present in use in Finland, and according to official returns the imports during recent years were as follows :—

		1926.	1925.	1924.
Motor cars	No.	5,138	4,111	1,781
Motor lorries	No.	17	61	340
Chassis for passenger cars	Tons	81	78	1,478
Chassis for commercial vehicles	Tons	1,338	1,589	

The most popular type in the Finnish market is a powerful six-cylinder light car, which can take the hills and the bad roads in the country without difficulty or changing gear. There is no petrol tax in Finland and taxation on the engine-power is very small, and therefore the car of greater power is preferred.

Commercial vehicles are also in considerable demand. The German omnibus chassis and lorries, which were formerly popular, have given way to the French, especially those of the higher quality, but not over three tons, which is the maximum allowed by the road regulations. A large number of the cheaper type American commercial chassis are also imported. The bodies of commercial vehicles and buses are now built in Finland.

GENERAL NOTE.

ROYAL STATISTICAL SOCIETY. FRANCES WOOD MEMORIAL PRIZE.—The Council of the Royal Statistical Society will again, in 1928, award the Frances Wood Memorial Prize, value £30. The prize will be awarded for the best investigation, on statistical lines, of any problem affecting the economic or social conditions of the wage-earning classes. Competitors, who must be under 30 years of age, will choose their own subjects, but it is believed that original observation or analysis made in the course of the writer's ordinary work or special research will afford useful material for papers. Essays must be sent to the Honorary Secretaries of the Royal Statistical Society, 9, Adelphi Terrace, W.C. 2 (from whom further particulars may be obtained), not later than October 31st, 1928.

THE LIBRARY.

The following books have been presented to the Library since the last announcement:—

Appleton, W. A., C.B.E. Unemployment : its Cause and Cure. London: Philip Allan & Co., Ltd., 1928.

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Blake, G. C., M.I.E.E., F.Inst.P. History of Radio Telegraphy and Telephony. London : Chapman and Hall, Ltd., 1928.

Carter, Roger, M.Com., F.C.A. Murray and Carter's Guide to Income-Tax Practice. Eleventh Edition. London : Gee & Co. (Publishers), Ltd., 1927.

Davison, Raffles, Hon. A.R.I.B.A. A record of his Life and Work from 1870-1926. Edited by Maurice E. Webb and Herbert Wigglesworth. London : B. T. Batsford, Ltd., 1927.

De Koningh, H. The Preparation of Precious and other Metal Work for Enamelling. London : Crosby Lockwood & Son, 1927.

Dictionary of National Biography, 1912-1921. Oxford University Press. (London : Humphrey Milford.)

Eberlein, Harold Donaldson and Roger Wearne Ramsdell. The Practical Book of Italian, Spanish, and Portuguese Furniture. London : J. B. Lippincott Company, 1927.

Fairchild, Prof. Henry Pratt. Immigrant Backgrounds. London : Chapman & Hall, Ltd., 1927.

Findlay, Alexander, M.A., D.Sc. The Phase Rule and its Applications. Sixth Edition. London : Longmans, Green & Co., Ltd., 1927.

Fowler, H. W. A Dictionary of Modern English Usage. Oxford : Clarendon Press. (London : Humphrey Milford), 1926.

Haydon, Judge, M.A., K.C., and Sir Gilbert Garnsey, K.B.E., F.C.A.

The Secretary's Manual on the Law and Practice of Joint Stock Companies. Twentieth Edition. London: Jordan & Sons, Ltd., 1928.

Houstoun, R. A., M.A., D.Sc. Intermediate Electricity and Magnetism. London : Longmans, Green & Co., Ltd., 1928.

Hudleston, L. J., M.C., B.Sc. Chemical Affinity. London : Longmans, Green & Co., Ltd., 1928.

Hunter, Andrew, M.A., M.B. Creatine and Creatinine. London : Longmans, Green & Co., Ltd., 1928.

Huntington, Ellsworth. The Human Habitat. London : Chapman and Hall, Ltd., 1928.

Huntington, Ellsworth, and Leon F. Whitney. The Builders of America. London : Chapman & Hall, Ltd., 1928.

Hussey, Christopher. The Picturesque. London : G. P. Putnam's Sons, 1927.

Johnson, A. F. French Sixteenth Century Printing. London : Ernest Benn, Ltd., 1928.

Johnson, Franklin P., Ph.D. Lysippos. Durham, U.S.A. Duke University Press. (London : Cambridge University Press), 1928.

Kingzett, C. T., F.I.C., F.C.S. Chemical Encyclopædia. Fourth Edition. London : Baillière, Tindall & Cox, 1928.

Layton, Edwin J. Thomas Chippendale : A Review of his Life and Origin. London : John Murray, 1928.

Lieu, D. K. China's Industries and Finance. Peking : Chinese Government Bureau of Economic Information, 1927.

Maxwell, Francis, D.Sc., F.C.S. Economic Aspects of Cane Sugar Production. London : Norman Rodger, 1927.

Moor, C. G., M.A. Tin Mining. London : Sir Isaac Pitman & Sons, Ltd., 1928.

Nutting, Wallace, D. D. Photographic Art Secrets. London : Chapman and Hall, Ltd.

- Palmer, L. S., M.Sc., Ph.D. Wireless Principles and Practice. London : Longmans, Green & Co., Ltd., 1928.
- Pijoan, Prof. Joseph. History of Art. Translated from the Spanish by Ralph L. Roys. Vol. 3. Barcelona : Salvat Editores, 1927.
- Russ, Sidney, D.Sc., L. H. Clark, Ph.D., and B. D. H. Watters, M.Sc. Physics in Medical Radiology. London : Chapman and Hall, Ltd., 1928.
- Smith, David Nichol. The Oxford Book of Eighteenth Century Verse. Oxford University Press. (London : Humphrey Milford), 1926.
- South American Handbook, 1928. London : South American Publications, Ltd., 1927.
- Trelease, Sam F. and Emma Sarepta Yule. Preparation of Scientific and Technical Papers. London : Baillière, Tindall and Cox, 1927.
- Wardlaw, William, D.Sc., F.I.C., and Frederic W. Pinkard, M.Sc. Qualitative Analysis. London : Longmans, Green & Co., Ltd., 1928.
- Wheeler, E., M.B.E. The Manufacture of Artificial Silk. London : Chapman and Hall, Ltd., 1928.
- Wimperis, H. E., O.B.E., M.A., and F. E. Smith, C.B., C.B.E., D.Sc., F.R.S. Physics in Industry. Vol. V. Oxford University Press. (London : Humphrey Milford), 1927.
- Winchester, Clarence and F. L. Wills. Aerial Photography. London : Chapman & Hall, Ltd., 1928.
- Wingate, Mrs. Alfred. Jên. London : Crosby Lockwood & Son, 1928.
- Yarrow, Lady. Alired Yarrow: His Life and Work. New Edition. London : Edward Arnold & Co., 1928.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

- MONDAY, JUNE 4.** Acturaries, Institute of, Staple Inn Hall, Holborn, W.C. 5 p.m. Annual General Meeting.
Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Business Meeting.
Civil Engineers, Institution of, Great George Street, S.W. 4.30 p.m. Sir J. Alfred Ewing, "A Century of Inventions." (James Forrest Lecture.)
Geographical Society, at the Æolian Hall, 135, New Bond Street, W. 8.30 p.m. Captain W. R. Hay, "Pre-Ghal in Waziristan."
Victoria Institute, at the Central Hall, Westminster, S.W. 4.30 p.m. Dr. J. A. Fleming, D.Sc., President's Annual Address, "Relativity and Reality."
University of London, at the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Dr. Marcel Mauss, "The Theory of the Elementary Forms of Prayer (Australia)." (Lecture I.)
At University College, Gower Street, W.C. 5.30 p.m. Prof. Max Bodenstein, "Chemical Kinetics." (Lecture III.)
- TUESDAY, JUNE 5.** Civil Engineers, Institution of, Great George Street, S.W. Engineering Conference.
Zoological Society, Regent's Park, N.W. 5.30 p.m.
University of London, at the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Dr. Marcel Mauss, "The Theory of the Elementary Forms of Prayer (Australia)." (Lecture II.)
- WEDNESDAY, JUNE 6.** British Empire Producers' Organisation, at the Royal Society of Arts, Adelphi, W.C. 4.30 p.m.
Civil Engineers, Institution of, Great George Street, S.W. Engineering Conference.
University of London, at the London School of Econo-

mics, Houghton Street, Aldwych, W.C. 5 p.m. Dr. Marcel Mauss, "The Theory of the Elementary Forms of Prayer (Australia)." (Lecture III.)

- THURSDAY, JUNE 7.** Chadwick Public Lecture, at the Chelsea Physic Garden, Swan Walk, S.W. 5 p.m. Prof. W. E. Dixon, F.R.S., "Narcotic Plants."
Chemical Society, Burlington House, W. 5.30 p.m. (1). Messrs. F. L. Gilbert and T. M. Lowry. Studies of Valency. Part X. Electrometric titration of Vernon's α and β -dimethyltelluronium bases. (2). Messrs. F. L. Gilbert and T. M. Lowry. Studies of Valency. Part XI. Molecular conductivities and extinction-coefficients of derivatives of *cyclo*-telluropentane. (3). Messrs. A. Key and P. K. Dutt. The action of diazo-salts on aromatic sulphonamides. Part II. The mechanism of the reaction and constitution of the diazo-sulphonamides.
Civil Engineers, Institution of, Great George Street S.W. Engineering Conference.
Royal Society, Burlington House, W. 4.30 p.m.
- FRIDAY, JUNE 8.** Astronomical Society, Burlington House, W. 5 p.m.
Geologists' Association, at University College, Gower Street, W.C. 7.30 p.m.
Malacological Society, at Burlington House, W. 6 p.m.
Physical Society, at the Imperial College of Science, South Kensington, S.W. 4.45 p.m.
Royal Institution, 21, Albemarle Street, W. 9 p.m. Prof. George P. Thomson, "The Waves of an Electron."
University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Dr. Julian Krzyzanowski, "Polish Culture in the Middle Ages." (Lecture V.)
At the London School of Economics, Houghton Street, Aldwych, W.C. 5 p.m. Mr. Philip Noel Baker, "Locarno and the Present Situation."

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*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C.(2.)*

PROCEEDINGS OF THE SOCIETY.

EIGHTEENTH ORDINARY MEETING.

WEDNESDAY, 18TH APRIL, 1928.

PROFESSOR A. E. RICHARDSON, F.R.I.B.A., Professor of Architecture,
University College, London, in the Chair.

The following paper was read :—

AMERICAN ARCHITECTURE.

By ALFRED C. BOSSOM, F.R.I.B.A.

American architecture is the skyscraper! If the United States ended to-morrow, the skyscraper, probably, would be looked upon as that country's greatest contribution to world development. Its history is a romance, and I will endeavour to tell you the intimate story of its early struggles, which—unless recorded now—will very likely be forgotten, as the men most concerned are fast passing away.

I would like at this point to emphasise my definite feeling that skyscrapers are totally inappropriate for England. Our cities are built on their old foundations of the 16th and 17th centuries, when three or four stories were the total height of the buildings.

Our sun is too low in the heavens to penetrate narrow streets if lined with mammoth structures; our atmosphere is loaded with dampness, frequently foggy, and the English temperament is opposed to such publicity, both in living and working, as this co-operative type of building compels.

Definitely, skyscrapers are not for us, but we can gather from their experience to our material advantage.

They pioneered in new architectural fields ; they have put a new value on Time ; they have utilised old-world knowledge and standardised constructions in ways that would be of considerable help to us and without our losing the beauty or charm of our English architectural character.

Forty years ago the present phenomenal age of invention started, and since then America has gathered and evolved a new building science. Never in the world's history has an architecture portrayed a nation's characteristics so accurately as does the skyscraper. It strikes a new psychological note, and, if we understand it, it will enlighten us as to many characteristics of the American people which often we misjudge.

America is peopled with those who, within this or recent generations, literally took their lives in their hands, crossed 3,000 miles of ocean into an unknown country and backed themselves unaided against unknown conditions. They were and are the first hand-picked great nation composed entirely (if the law of selection means anything) of pioneers along both mental and material paths.

I have known villages of 200 grow into cities of 20,000 in five years owing to the discovery of oil or some other natural wealth-producing product, and what did this cause ? The shoemaker who went there had to shout " Shoes " to make a livelihood—no one knew him otherwise. The man needing a coat had to shout for the tailor otherwise he might have frozen ; in other words, the law of self-preservation compelled all to state their abilities and wants very audibly.

In Europe we know the life history of the majority of our friends and neighbours ; hence, we look surprised, often shocked, at the very forceful methods of the Americans, but that is the outgrowth of a very pressing necessity of early days so as to obtain the wherewithal to sustain life, and this quality has been most instrumental in the skyscraper's prodigious growth.

Competition among this gathering of keen-witted adventurous people has stimulated their inventive and appreciative qualities, so that they react quickly to natural impulses and with more enthusiasm and speed than would be natural with us, and they are such a mixture of peoples that they are untrammelled by tradition.

The qualities of light have a great effect on architecture. Egypt, for example, with its intense blue sky and dry atmosphere, has deep black shadows ; hence its architecture had no heavy projecting mouldings, but consisted of large flat surfaces with plain rounded columns, which were scratched to tell a story, but not to form decoration. Everything in mass was big, bold and simple.

In Greece and Rome the brilliant Mediterranean sunlight combined with a damp atmosphere produced glorious colours in the shadows—oranges, lavenders and purples ; hence, these people fluted their columns and ornamented their deep cornices to gain great richness out of the parts in shade.



*An Air View of New York City.
Reproduced by kind permission of *The Builder*.

As we travel north in Europe's Gothic belt (France, Germany and England), we encounter grey days when the sun is often absent. What happened? Men cut beautiful forms on their walls with tracery windows, built vertical projecting flying buttresses and pinnacles which added charm and gave delight irrespective of the weather. Horizontal projections were not attempted as shadow beauty was so uncertain.

As to North America. The light is peculiarly white and the shadows are uninteresting. This applies generally over the Continent, and if we investigate what happened in Mexico Yucatan (where, in fact, lived the Mayans, perhaps the most intelligent aborigines the world has had), we find they evolved an architecture amidst high vegetation that was aspiring, and towered to the sky. They had no cornices, but simple surface decorations, but they strongly ornamented the angles of their buildings and pyramids for a silhouette, as shadows had so little value.

By a process of natural evolution, the light has caused the skyscraper also to adopt this treatment of flat surfaces, set-backs and ornamented silhouettes against the sky.

This law of light is apparent in architecture throughout the world and holds, except where it has been deliberately altered by some outside influence.

Again man, having a finite mind, creates a living architecture under a finite inspiration. The Chinese, Persians, Egyptians and Hindus produced their finest works as temples or shrines to visible deities. Greece and Rome built their masterpieces as settings to gods they worshipped and of whom they had a representation before them. The great Gothic age, which produced the wonderful cathedrals, was another example, for those buildings were literally shrines to symbolical statues representing saints, the intermediaries between man and his God.

But what happened at the Reformation and since? Old forms were revived, but new ones were not created. Very beautiful and intensely delightful combinations were worked out, but the new, the result of inspiration, is not evident.

If we examine the Hebrews, perhaps the most close-knit race in the world, they were denied a graven image, and we find they have produced no appropriate example of their own architecture.

But America has again provided the visible inspiration: she worships Success. Every successful family or corporation constructs a mighty building and names it after itself. The designer is inspired to do something new as a fitting background to his inspiration. Skyscrapers have resulted.

I referred a while ago to America's advertising capabilities. These huge buildings stand for 365 days and now, with flood-lighting, 365 nights each year announcing the success of their owners. They induce the growing child to be ambitious and undoubtedly have been responsible as an inspiration for much of the go-ahead character the United States possesses.



*First National Bank, Jersey City, New Jersey. (Alfred C. Bossom, F.R.I.B.A., Architect).

What is a skyscraper ?

It is a building of many stories, one piled on the other. These have existed in other countries, but those of America are different and have grown to their colossal size as the result of three conditions : the steel frame, the wire rope and a new form of foundation. In 1884, an architect named Buflinger, of Minneapolis, applied for a patent for a steel frame construction 28 storeys high.

By 1888 this was settled ; but such is human eccentricity, I believe he is still practising in Minneapolis, but has never designed a skyscraper which has been built.

Then came Robling, the engineer who invented the wire rope, the great designer of the Brooklyn Bridge. With this, the electric elevator was possible, and without it a fifty-storey skyscraper would have been practically impossible; and, lastly, Francis H. Kimball, the architect, in the latter part of the last century introduced into the construction of the Casino Theatre building on 39th Street and Broadway, New York, a caisson foundation which formerly had only been used for bridge piers in the beds of rivers.

Since the establishment of these three elements just forty years ago, the entire American skyscraper development has taken place. During these forty years there has been more wealth expended on skyscrapers in the United States than was spent in the entire four centuries of the great Gothic era of Europe. Never has a building development like this occurred in the world's history.

It is amusing to look back and see what existed before 1888. Architecture was at a pretty low ebb in the States: there had been a few six and seven-storey buildings largely made up with cast-iron fronts; several of these are still standing in Broadway. The outside was terrible and the inside was appalling, and the architecture of that age became known to the world as the era of the Early Pullman or the late German Lloyd style.

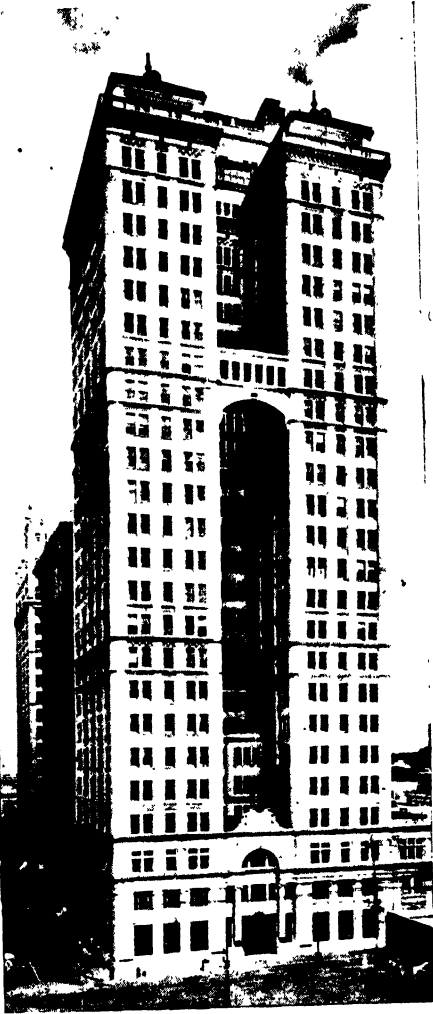
Architecture then was not what you might call an exclusive profession, as "Architect and Coal Merchant," "Undertaker and Architect," "Architect and Carpenter," were the signs on many of the shingles, to use an American expression, that were hung up by the men who wished to design buildings.

New York is often given the credit of starting the skyscraper activity, but actually Chicago urged the development at first. Owing, however, to that city's mud foundation, Chicago's method of construction consisted of creating a great concrete raft or platform, and then erecting the building upon it. These entire structures often sank a foot into the ground on completion; New York later started the caissons principle, digging to a rock foundation, and this made the later tremendous height possible.

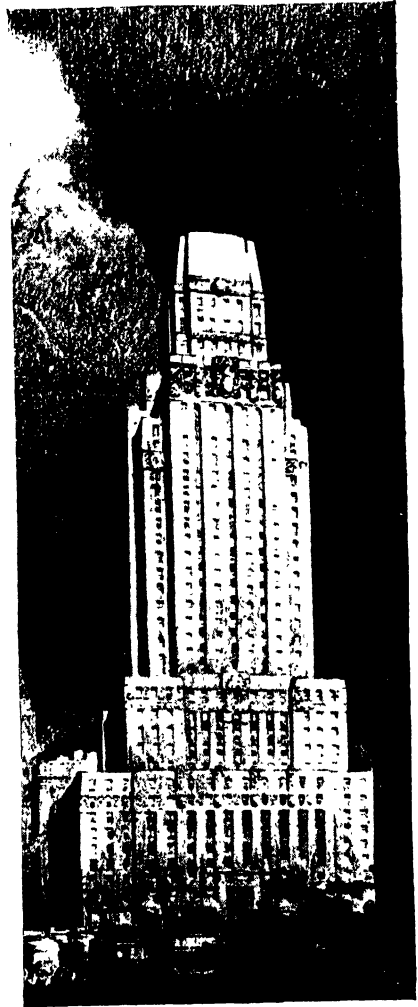
You will appreciate how recent all this is when I tell you that Mr. Robling, of wire-rope fame, was one of the directors of a bank-owned skyscraper I finished but a few years ago in Trenton, New Jersey, and F. H. Kimball, who first employed the caisson foundation, and myself were associated professionally on more than one occasion.

The introduction of the steel frame almost turned building materials into living substances. In the past, the weight of a heavy roof or beam had been supported by a thick wall or a flying buttress, which balanced a weight from above by a mass of masonry below.

But the steel frame did not do this; it provided slender supports as near 20-ft. apart as practicable, steel staunchions which continued from basement to roof, and then tied these together at each floor level by girders. It formed a skeleton upon which the building hung. In fact, the skyscraper approaches



*Magnolia Petroleum Building, Dallas, Texas.
(Alfred C. Bosson, F.R.I.B.A., Architect.)



*Thirty-four Storey Building designed from
Primitive American Motives. (Alfred C.
Bosson, F.R.I.B.A., Architect.)

as near to a living entity as a man-made object reasonably can, and the nearer it gets to this, the better skyscraper it becomes.

Its foundations or caissons are like great toes that burrow into the ground to hold it firm. On these stand the steel columns or staunchions tied together with girders forming the skeleton like our own. The joints are made allowing for wind force and strain by gusset-pieces and stay rods (wind bracing as it is called) which takes the place of our muscles. The dermis or epidermis is formed with a thin layer of brick, stone, marble or metal, thinner in the

case of a 40-story building than for a 3-story building in England. The top is crowned with its decorative silhouette against the sky which forms a head. It has nerves, electric wires and telephones circulating to every room and almost every part of each room. It has arteries that pump hot and cold water to every room and veins or waste-pipes that carry this away. Its heating system is similar to our blood circulation. It has lungs in the form of a ventilating system that changes the air through these vast structures by the minute; its engine room is a heart and brain combined which gives its life-giving qualities to the building by forcing its elevators up and down, and it is capable of repair to its parts without destruction of the whole.

I remember very well an example of this in a skyscraper hotel in Texas to which I was making a 22-storey addition. On one occasion the manager rushed to my room terribly worried as the floor of the main lobby had settled two inches; he was afraid his entire building might collapse.

We went to the basement and knocked the concrete fire-protection away from the column under the settled portion, and found that the fumes from the adjacent refrigerating plant had seriously rusted this particular column so that it failed, and the girders in the floor above settled, but the gusset-pieces I referred to before as muscles held these girders together like a bridge with perfect safety; all that had to be done was to cut the old column out and put a new one in its place.

It is interesting to answer a very common criticism that we do not know how long steel buildings will last. That, obviously, is true, but we do know they will not collapse any more than one bad stone in a wall will bring about the destruction of a building.

There was a building on Fifth Avenue to which an addition was being made, and of the seven steel columns in the side wall, six were perfect, but one had rusted. In Galveston, Texas, the salt air and dampness penetrated the fire-proofing and concrete protection and rusted a rather important girder in a tall bank building, and I can recite you many instances, but this rusting, if it develops, only occurs very slowly in isolated spots and never throughout the entire frame, and already a form of X-Ray machine is practically perfected which will enable an inspection of the steel frame to be made through the walls, disclosing if it is either spongy owing to electricity passing through it at some point, or rusting. In either case, if a trouble is discovered, it is practicable to repair the damage without much difficulty. Iron will last, for we now have good specimens of work from the iron age.

In the early days, these buildings were appropriately criticised; every one really was an experiment, but the U.S.A. was like to a virile young man of vast strength, initiative, and wealth, possessed with the abounding desire to do something that has not been done before. This spirit was infectious; architects were not unaffected; it was an era of experimentation and from it came much that can be turned to the world's benefit.

It was all so quick, so recent, that those terrible eye-sores that were constructed first, still stand like sore thumbs in a landscape, but these are slowly being eliminated.

Those early buildings often looked like poor little Greek temples or half-baked wedding cakes perched up on packing cases. They were gawky, frequently infested with ornamentation; columns, swags, fat boys and bulbous maidens sprawled all over the place; it was an entirely new problem and all were groping for the answer, but in spite of this some most interesting buildings resulted.

There were very few architects in the early days who were entrusted with these buildings; later more trained architects joined in. Practically all came to Europe for education, but the European eye was tuned to the horizontal major axis for a building, and it was some time before the new importance of the vertical axis was fully appreciated for the design of tall buildings.

These troubles were slowly overcome. Men like Sullivan, of Chicago, started to form buildings on new lines, attempting to give a great sense of strength, but the movement did not gather force though the desire for tall buildings grew.

At first an owner was content with the tallest building in his town, then it was the highest in the State, later in the United States, with the result that the era of mammoth building began.

First the Singer building held the palm as the tallest in the world, and owing to its prominence it is rumoured that it got so much advertising for its owners—and I believe with truth—that they sold enough additional sewing machines in Asia alone during its first year of completion to pay for the building.

Next up shot the great white marble Metropolitan Tower on Madison Square designed by the brothers le Brun, but this did not hold the record for long, for Woolworth, the Napoleon of the 5 and 10 cent stores, instructed his architect, Mr. Gilbert, to overtop it, and this—the world-famous Woolworth building—was really the first one that embodied the real principles of verticality in design.

Although Gilbert borrowed his detail from the Gothic times, he put it on a structure or skeleton that told its story truthfully. It was a steel-framed building and looked it. That building held the record for many years, but at the present time I think the Bok Building in Cleveland, an 81-storey structure, the 100-odd storey Harmon building in the centre of New York, has already, or soon will, lead the field.

No one expects that 100-storey buildings will be at all an unusual structure 10 years from now.

But to get back again to the early days of this new skyward pioneering. The few of us who were designing these buildings all knew each other and

watched with a most intense interest what the others were doing—not with the idea of copying, for every building was a new adventure, but seeing what we could learn from one another, and how we could improve on each other's efforts and constructional methods.

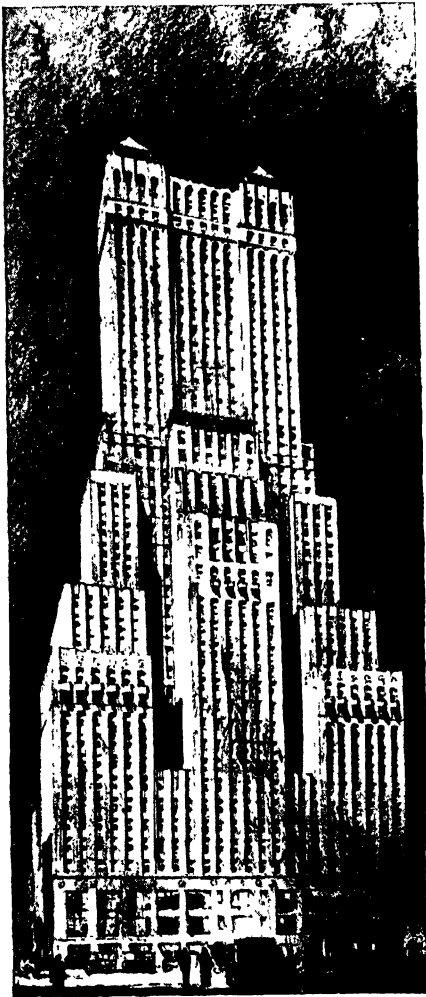
It is interesting to look back ; how little real jealousy there was, how the older men and the younger men discussed and helped each other, and the romance of how each came to be entrusted with his first big building is a story that I hope will some day be told, as it will be a most creditable commentary on the architects of that new country. I believe it would be a revelation to hear how those men helped each other in the most sporting spirit and how each gave out freely all the results of his own investigating.

To give one instance—in about 1910, when the Gillender building, not 20 years old, on the corner of Broad Street and Wall Street, was being pulled down to make room for the Granite Bankers' Trust Tower (around the top of which Mr. J. P. Morgan had a private promenade), we all watched it being torn to pieces to see what could be learned, for many buildings had suffered with their pipes which so far had always been buried in the cinder concrete which composed the floors, but the sulphur destroyed the pipes. One short piece of the pipe was discovered which had not been affected, and on examination it was found that accidentally one of the men when the building was originally built must have been having his lunch and when putting that pipe in position, had left the paper on the floor and it had become wrapped round the pipe and that had prevented the sulphur doing its detrimental work. From that time pipes were wrapped in tarred paper to protect them if buried in cinders. This soon became known all over the country, and for a time was the current practice until we were able to find a more satisfactory method of protection.

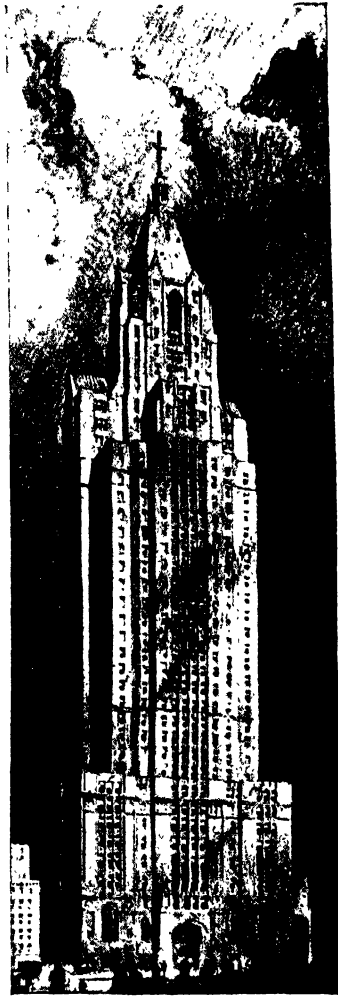
Those early buildings were seldom great financial successes, owing to the lack of knowledge of how to design them. Many were quite poor investments. Tenants did not move in as quickly as desired. In 35 Broadway—I believe it was—just about the end of last century, a man who had just organised a bank nearby, was invited to move into the ground floor and live rent free with his bank for five years, and the owner of the building offered to give him \$100,000 to spend in arranging his banking quarters. It was thought that by so doing the bank would bring many of its customers into the building and make it a good investment.

Later, the architect, in order to be successful, had to be a very sound business man, capable of calculating accurately how tall a building would pay in any town or place, and the more expert he became at this financial side, the more important his practice became, and that is perhaps why successful architects are so highly respected in the U.S.A.

Of course, each of these early buildings made their owners very conspicuous, and this caught the eye of the keen speculators who thought they saw



*Building designed for Madison Avenue and 50th Street, New York City. (Alfred C. Bossom, F.R.B.A., Architect.)



*Proposed Church and Office Building, Dallas, Texas. (Alfred C. Bossom, F.R.I.B.A., Architect.)

possibilities of money being made from these new-typed buildings, and from these men, mostly bankers, came one of the real contributions the skyscrapers have made to world industry. They saw that the buildings to be money makers must be constructed quickly owing to the large interest charges involved, for the cost of these buildings was so tremendous.

The mere crowding of men on to the job would not do this, and I think that the credit is largely due to Mr. Huntingdon, a Canadian, and now a very prominent contractor in London, who was the first man to devise a

workable schedule of building progress just after the beginning of this century. It was very primitive in those days, but the plan was to arrange that everything should be brought to the building at the right time.

Since then this plan has been developed and is worked out graphically—often before the building contract is signed and before the first spadeful of earth is turned on the ground.

These buildings are not built in the usual English sense, but are assembled ; every part coming to the building practically complete, only waiting to be put into position and affixed to its adjoining elements.

The progress schedule shows the date when every portion of the work shall start and must finish. It indicates the number of men required in each trade or work so as to get each section finished in time ; it shows the general contractor when he must let all of his sub-contracts, such as his stone-work, his steel-work, his window frames, etc., and when the material must be at the site ahead of the time needed and yet not so far as to encumber it with unneeded material.

This has now become a most exact study, but even in 1910 it was well advanced, for when I was doing a 20-storey building costing about three quarters of a million dollars—which in those days was a big fellow (this was to be the headquarters for the C. & O. Railway in Richmond, Virginia)—the contractor was instructed that it must be completed exactly in nine months.

It took a little over three months to put down the foundations which were dug by hand by open cut method nearly 80ft. into the ground, and I can assure you that I almost got housemaid's knees praying that none of the shoring would ever give way in the holes while the men were doing that digging. It was all made ground and a failure might have been very serious. The foundations finished, it left a trifle less than six months to complete that 250-ft. high building.

The railway officials moved in on the day they desired, which would have been quite impossible had it not been known in advance where everything was coming from, where to put it and what to do with it when it arrived.

But other things were taking place. Those banker owners insisted on the buildings being financial successes, and they pressed the architects to cut down all decoration.

Cornices of 10-ft. projection had not been unusual, but were certainly expensive. Clients insisted in reducing these. They slowly pressed back all projections to save materials, which also meant saving money, until finally there was little left beyond thin bands on a brick wall, and that was the time when skyscrapers looked like huge packing cases with holes cut in them for windows.

At the same time these clients endeavoured to cover the land as much as they could, thinking they would squeeze more return from their investment by so doing, and it is during that period that the world-famous canyons of Broadway and Wall Street were built.



Proposed Memorial Bridge over the Hudson River.

Nearly every room up to the sixth floor of these older buildings has had to be lit by artificial light ever since.

There was justice in the desire to cut off the cornices, for when I had my office on the 17th floor of the Flat Iron building in 1905, a part of the terra-cotta cornice fell down and made a hole in the pavement as though a bomb had dropped. The reduction of these weighty projections was obviously a good thing, but the buildings became so uninteresting and the land was getting so overcrowded that the architects revolted.

Slowly a great deal was learned, and we did not wish to ruin the great cities by overcrowding them with structures or by putting up bad ones, and this resulted in the City of New York passing a Zoning Law in 1916. This is an American interpretation of the Law of Ancient Lights and has a great sense of justice in it, as it applies equity to everybody instantly by rule, which can hardly be said to be the case with its parent the English Law.

These zoning laws determine how high a building could go vertically from its building lines. It settled the height as of one, one-and-a-half, etc., times the width of the street, that the front face of the building could be vertical, but above that point it could be carried up to any height provided it stayed behind an inclined line definitely and legally determined.

I had been to Mexico and studied these pyramids carefully and knew of the advantage of this arrangement. This setting back had to take place not only on the street front, but also on the rear of the buildings. The law also limited the amount of cornice that could be constructed and the area of the dormers that could be built; it settled the maximum size and use of a building on a piece of property, thus determining that all must have at least the minimum amount of light and air which was essential under any circumstances. There was one interesting proviso in this law: that a quarter of the area of the building—no matter what size—could be carried to any height, and this stopped the box-like structures and opened an entirely new range of possibilities.

No doubt you have heard that these buildings sway. Well, they do, but not as is usually implied. On one of my buildings, which was 450 feet high, in Dallas, Texas, we once experienced what is called a Norther, a great wind rushing at about 70 miles an hour, which lasted for three days. We kept most exact measurements of the movement of that building, and it leaned just 10 inches out of plumb in that 450 feet of height, which is just about one-fortieth of an inch to the foot, which is almost too small to measure except on a building of such tremendous height. It took three days to bend the 10 inches and it took about three days to go back again.

The swaying idea started, I assume, owing to the shaking of pictures, etc., on the walls in the upper storeys of these buildings where the windows leaked. This was caused by the inability at that time to prevent the wind from driving through the window frames; now metal weather strips (which, by the way, are unobtainable in England) can cut out any wind or rain coming through a window, no matter what pressure. These have a double advantage: they prevent unnecessary waste of heat, so much so that many buildings have saved probably one-third of their coal bill when properly weather-stripped, and they also prevent the petty illnesses of colds, coughs, stiff necks, etc.

I do not wish to give the impression that these buildings are made into air-tight boxes; they are so arranged that when a driving wind is coming from one direction, the windows on that side can be closed and the air circulates

by opening the windows on the other sides and through the elevator and vent shafts, etc.

One often hears criticism of American workmanship, mostly made by those who have never seen these buildings. Formerly there was justice in that contention, but a great many of the best European mechanics are unfortunately being attracted to the U.S.A. by the high scale of wages, and it is they who are building these buildings now. I am ultra conservative when I state that during my time in the United States I have come in intimate personal contact with the work of many hundred thousands of European mechanics, and I have not the slightest hesitation in saying that the work they are doing in America would compare favourably with the best work they did at home.

The impression has gone around that America is filled with these great buildings; there are a tremendous number, but America is a tremendous country and the average height of Paris at the present time is about one and one-fifth storeys higher than the average height of New York, for practically every building in Paris is six storeys high or more, whereas the skyscrapers in New York are in masses in the centre of the city, whereas the remainder is only four, three and two storeys high.

These buildings are arranged to meet a twentieth century condition. Many European buildings are built to-day as well and as perfectly as they were fifty years ago, but really do not provide for the future introduction of many improvements which are certain to come. The skyscraper does this in two ways: it is calculated on a financial plan that enables it to be scrapped, if desired, within a period of thirty years at most should the new inventions become too numerous to incorporate within the existing building, and it also arranges that all pipes or conduits for utilities, heating, electric work, etc., are placed in open chases or channels, and can be removed without destroying the structure.

Each floor supports upon itself everything that stands upon it, such as partitions. These buildings have no permanent or structural divisions except staircases and elevator shafts, so that it is possible to readjust them for quite a new purpose or to incorporate new improvements without great expense when desired.

Many English people visited New York years ago and stayed in the Manhattan Hotel, in 42nd Street and Madison Avenue, or the Knickerbocker Hotel on 42nd Street and Broadway. Both of these buildings have already outlived their usefulness as hotels, and have successfully been converted into office buildings.

One of the very first skyscrapers built—No. 1 Broadway—has been re-fashioned and now is the very up-to-date headquarters of the International Mercantile Marine Co.

These great buildings have developed many new industries. Take steel; we will admit that much standardisation is not an unmixed blessing, neither is it an unmixed curse, as many claim it to be. These buildings have proved

that if columns be placed about 20 feet apart, it is possible to work out a steel construction arrangement that will allow the widest possible elasticity of interior arrangement, and so the rolling mills make sections, i.e., beams, that can be used with practically no handwork upon them, which results in the minimum of expense and maximum of speed in construction. Steel door architraves, windows, etc., come to the buildings all ready and only have to be placed in position, saving at least two-thirds the time taken to set ordinary door frame architraves, etc., and are permanent and indistinguishable from the old type when painted.

The open plumbing of America is a byword. The handwork on lead pipes is entirely eliminated; it is all comparatively standardised; steel or brass pipe is used and the work is done by the plumbers in their shops under convenient and comfortable conditions, and all reasonable labour-saving devices are provided. Connections are made with screwpipes, so that the work can be done in less than half the time that the same men would take for the same work under former methods; in fact, in all trades a great effort has been made to allow the mechanic the opportunity of doing his work under the most comfortable and practical conditions and also to supply him with all possible information and helpful devices or machinery, so that he does his work well and economically.

As to lighting, where that has to be artificial, it is usually the equivalent of artificial daylight with the red component, which is the cause of eye-strain, eliminated, and the blue and yellow introduced to cut out one of the chief causes of nerves and headaches.

Ceilings are treated with absorbent plaster to prevent the worry created by the tapping of typewriters and adding machines, or in restaurants or factories, and at least two-thirds of the undesirable sound is suppressed or absorbed.

As to ventilation, fresh air is pumped from the roof and washed and warmed and then driven where required.

Regarding fire-protection, not more than two elevators or lifts are allowed in any one shaft, although there may be a dozen in the battery or row. They are so divided that should a fire occur the smoke cannot pass from one shaft to the next, and the general fire-proofing of the building is such that, although a fire probably occurs at least once a week in every large office building owing to some careless tenant throwing a lighted cigarette into a waste basket, the fire is extinguished without the knowledge of the tenant in the adjoining room, and without injury to the building outside the room concerned.

The exterior walls are made as thin as possible, treated with water-proofing shot at them with a paint gun, which not only gives speed but a very efficient method of doing this work. These guns are becoming an important element in building generally, for not only are the walls painted with them, concrete shot from them, but large architectural drawings are frequently coloured with them. A small study just a few inches high is made; this is enlarged by photo-

graphy up to several feet if needed and then coloured with an air brush or small paint gun—a quicker and more effective process than the older method and quite as artistic.

These are only a few of the detail developments, but the commercial thought has now come into force which is again changing the actual use of these. Some of these buildings actually hold several thousand people, and they are beginning to have uses different from the old days. Formerly an apartment house, hotel or office building was complete by itself under its own roof. Now, with great size and abnormal traffic congestion, some of these buildings are beginning to have shops on the ground floor and a bank on what would be our first floor entered direct from the street. The next half-dozen floors or so are general offices or show rooms, and the upper set-back section is used for apartments or an hotel with individual gardens.

The man may work in his office, and instead of going away by his motor car to his home, he goes up in the lift to his own apartment or flat, which is three, four, or five hundred feet above sea level, and he is relieved of the fatigue of the journey back and forth which is so irksome to-day in almost any crowded city, but, what is more important, it allows him the maximum of his time for leisure or any pleasurable diversion he likes.

These living quarters have their own gardens. I know one in Houston, Texas, owned by William Hogg, which has trees growing round it, and I mean real trees. It has a grass lawn and flowers. Another in New York has an artificial pool on which the children of the family row a regular rowing boat.

This plan of mountain-high homes in the middle of a city is new and is only just starting; what the future holds, none can tell. One building of this kind has just been designed of glass. These buildings are full of the unexpected; the first era of their development is finished; we are entering the second.

Buildings are getting of larger size both on the ground and in the air, and it seems that each building in the natural course of events will occupy an entire block frontage of about 200 feet on the street, which means that the living towers will be 200 feet apart, getting better light and air than the average two-story building in a narrow street.

In conclusion, I would like again to call attention to a few matters I have touched upon. I hope you will excuse my repeating, skyscrapers are totally inappropriate for England, but we can learn something from these abnormal and rather unique constructions which America has produced.

First, in building they are organised so that one costing a million pounds may be completed satisfactorily in fifteen months; we can easily do the same if we wish, and it means that the benefit of income from the new building is available so much quicker. We certainly have complained enough about our slowness in building, and I do not feel it is the fault of the workers—we do not give them the needed help. We set up an outcry against standardisation, but where the standardisation is invisible—as it is in the steel construction—

and leaves every latitude for any arrangement and future change, if desired, and at a considerable saving of money, why should we not consider this in all of our new commercial buildings? Who knows what may be forthcoming from some inventive genius to-morrow that will make life a little more desirable if added to our buildings?

I feel we should look into such matters, for we do not want to waste money in England now that prosperity is not so abundant and taxes are as high as they are. If we can use steel more freely and economically, we are helping our basic industries; we should be giving Englishmen employment and keeping the money at home. We should save buying lumber from Scandinavia or bricks from Belgium, make building cheaper and help the unemployment situation.

Skyscrapers have so affected the science of building that they have definitely established facts which have been verified on both sides of the ocean.

Identical buildings to-day would have the same total cost in New York or London. If we take an example of a building costing one hundred thousand pounds, in England we should spend sixty thousand pounds on materials, and forty thousand pounds on labour salaries, but in America the reverse would be the case, i.e., forty thousand pounds for materials, and sixty thousand for labour, and remember the unit cost of material is the same on both sides of the ocean. This means that our building laws and building practices are of such a nature as to compel us to use 20% more materials in our buildings than would be the case in the U.S.A. Again, the men work equally hard in both places, but the man in England gets a trifle less than one-third as much per week for his effort as the mechanic in America, and, what is more, owing to a certain lack of organisation, waste of time and absence of labour-aiding devices and obsolete methods, he has to work nearly three times as long to complete the building.

If we would consider these facts and revise our building laws, we could easily pay our mechanics half as much again, have them work no harder and yet have buildings completed in less time and at much lower cost. We could easily make a tremendous saving—quite possibly 25%—if we used materials as needed and not as dictated by obsolete traditions, which have passed for ever, and if we gave our mechanics aid and appropriate information. Do you realise what this means? It means that every person in this room—in fact, each one of us in England—is actually doing the same as dropping pounds annually down the sewer and not aiding anyone by so doing, for this waste of so much national wealth is shared by everyone. This is not a theory; these are proved and demonstrated facts, but what are we doing about it?

We should certainly insist on a consolidation act for all our building laws. For example, the L.C.C. to-day is actually building its own housing accommodation outside the administrative county of London on a cheaper basis than it can allow anyone else to build or can build itself within London's limits, owing largely to the London Building Act not being up to date.

We have been told that building is a seasonal occupation. You have seen the Liberty Bank at Buffalo where they were building in zero weather. It is not necessary for workers to continuously lose work owing to our inclement weather. If it rains, does the postman not bring your letters, does the policeman go home?—they put on overalls and go on with their job. The same thing can be done with building mechanics if the contractor provides the essential protection against cold or rain. They would then earn a full six days' wages for each six days in the week. Buildings built cheaper and quicker mean bigger salaries for our workers; it will enable the contractors to get more profit; it would be a material aid in meeting our slum clearance and housing conditions without such a drain on taxation.

Building would become an attractive investment and there would be more buildings built. Obsolete structures of no artistic or historic interest would not be used long after their years of usefulness have passed.

The traffic situation can also be aided. Many of the buildings we have seen to-night suggest a way. Provision can be made to have pavements in future inside instead of outside the building walls when the vehicular traffic makes the existing roadway widths insufficient; hanging bridges across streets where the traffic is dangerous to the pedestrian and walking balconies on the first floor level to form a pavement above the roadway are also possible. This would increase the value of our buildings and our architects are fully clever enough to make this of satisfactory appearance. We can by means of building aid our basic industries, help unemployment and bring British prosperity nearer again and without sacrificing any of those things so dear to all of us.

Ladies and gentlemen, I do hope I have given you a little food for reflection this evening. These buildings, abnormal as they may look, are the physical embodiment of the philosophy of this inventive century. The world is passing from a glorious age wherein everything was stabilised by years of tradition, but is entering a still more magnificent era, and if we will but exchange the benefits of each other's experience, we shall hurt no one and all will be the gainers.

We must admit machines multiply man's power of ingenuity and give him control over forces which yesterday would have been impossible.

Are we going to deny to England aids to prosperity which every other nation in the world is working day and night to turn to their advantage?

England never hesitated to give lavishly of her knowledge at the time when she was doing most of the world's experimentation, so now if we can find any nation that has developed new methods that would be beneficial to us, why should we hesitate to exchange knowledge with them?

I had a most interesting experience in New Orleans once. I was asked by the Hibernia Bank if they could have a building twice the height of anything in Louisiana. New Orleans stands in the delta of the Mississippi. I always had a theory that no delta existed naturally and that at some time there must

have been some solid layer upon which the silt could pile up, otherwise it would have simply been an arm of the sea.

With a contractor, a pile-driving machine and two 60-foot wood piles, we went to an open lot and drove the first. It went down several feet at each blow until about fifty feet in the ground; then it stopped almost dead. From that point the driving was slow, but after about eight feet more, one blow, and the pile shot into the ground out of sight. The pile-driving machine was moved to another spot and the same thing happened to the second pile. This proved that at a level of about fifty feet beneath there was something solid.

An auger was obtained. This forces to the surface the matter through which it passes, and we found at a level of about fifty-two feet below the city a layer of prehistoric oyster shells about eight feet thick which apparently had never been discovered before. With this information I went back to the bank and told them we could build practically anything as we had the desired solid base to start from.

DISCUSSION.

THE CHAIRMAN said it was interesting to recall that the building of the Royal Society of Arts, in which the meeting was being held, was erected at the time of the War of Secession. Going back to the seventeenth century—only 300 years—one found pioneers from this country and from Germany, Holland and France founding a new land overseas, taking with them certain traditions from Europe. Those early pioneers, in the architectural sphere, brought with them the primitive mediæval traditions, and the earliest work in America—log cabins, and so on—was inspired by the old spirit of mediæval craftsmanship. Then came the eighteenth century, with fresh inspiration from England, the style of architecture being slightly modified by contact with timber, and a new expression coming in. Then followed the Republican period, when architecture became more American and more individual. During this period America was much influenced by French classicism, and American architects adopted the classical tradition. One of the Presidents of the United States at this time—Jefferson—was himself a great architect. Then there came the period of the romantic and Gothic revival, which still looked towards Europe. Finally, there came the reign of terra-cotta with Richardson's Romanesque, and finally a revival of the classic again in 1893 at the Chicago Exhibition, with a reversion to French designs of the Napoleonic period, and America was given what was called a new Columnar style.

The early skyscrapers reflected that in a vertical direction. About that time what Mr. Bossom had called the "Early Pullman" and "Mature North German Lloyd" styles were creeping in and leading to a confusion of thought. In the end all that was shaken off and something decent emerged. The zoning regulations which the author himself had helped to bring about then came in and completely altered the silhouette of the skyscraper.

A similar development was not possible in England. A time might come when the By-laws would be altered and buildings up to 100 feet permitted. In the eighties, when Queen Anne's Mansions were built, London had a shock. Those buildings, indeed, still gave one a shock. They were of the square box type, but meant an advance in the right direction. Had there been more of those buildings

there might be less of the tendency for London to spread out into Bedfordshire, Hertfordshire, Surrey, and so on, and fewer of the bungaloid growths which had, unfortunately, taken place. We in this country had certainly spoilt the land horizontally, and though the American buildings were called skyscrapers they did not spoil the sky. The wonderful buildings Mr. Bossom had shown were certainly an inspiration to all architects though we did not want them in London.

With regard to the schedule of progress Mr. Bossom had referred to, that would certainly be used in England if architects had the work to do, but the majority of English architects were occupied with whitewashing, bathroom additions, and so on! Mr. Bossom spoke of the early architects in America calling themselves undertakers. In this country a good many architects were undertakers even to-day, for they were busy burying their own reputations.

SIR DANIEL KEYMER, O.B.E., thought all Englishmen and Londoners in particular should be very proud that it was a Londoner who went to the United States and gave the architects there a lead in the putting up of the fine buildings which had been illustrated that evening. The lecturer had suggested that in England we were behindhand in certain things, and had also intimated that he himself was giving up the architectural profession for what might be called the architecture of Empire, and he understood that he intended to seek election to Parliament for that purpose. If he was as successful in that direction as he had been in his architectural work in America this country would have cause for satisfaction, and he hoped Mr. Bossom would be successful in his new role.

SIR ARTHUR HOLBROOK, K.B.E., M.P., thanked the lecturer for his exceedingly informative address. He agreed that English people were slow-moving and took a long time to adopt new ideas, but they had achieved a certain amount of progress, as was evidenced by the new Regent Street. He did not know whether the new buildings there were to be regarded as forerunners of the skyscraper, but they were, at any rate, nearer the heavens than the ones they replaced. Some of the buildings had gone up more rapidly than he had thought possible; they had adopted the method of steel frames covered quickly with cement or stone blocks.

He had been much struck by what Mr. Bossom had said as to the organisation adopted in America to ensure the speedy construction of buildings according to a time table. There was much room for improvement in that direction in this country. A new town hall was being built at Paddington, and it was a very slow process because the material was not assembled at the time it was required. Organisation on the system the lecturer described would make possible much greater progress than could be achieved at present.

He had recently had a talk with Mr. T. P. O'Connor, who went to New York a short time ago for a rest, and was so alarmed at the height at which he had to live, and the noise—which seemed much greater in New York than in London—that he had to leave in order to recover his nerves!

MR. REGINALD W. HUKÉ pointed out that building work in this country, although dwarfed by that in America, was much more thoroughly done than the lecturer appeared to imagine. For one thing, the progress schedule which had been referred to, was in use in this country; when he saw the example shown on the screen he thought at first it must have been copied from that used in England. He wished it could be more generally adopted. In America it seemed possible to get hold of building sites completely much more quickly than could be done in London. Under

the conditions in which work had to be done in this country one could not possibly get a schedule out to complete a building in nine months, because many jobs had to be begun long before it was certain how much land was going to be obtained. Moreover, in America it was possible widely to adjust the building as one went along, but under the London Building Act it was not easy to do that. The London Building Act had a very restrictive tendency and did not permit the erection of high buildings, but if that Act were altered it would be found that English architects were not behind their American confrères, and would quickly take advantage of the new possibilities. Most people, however, did not want to see London changed. He recommended those interested to see some new buildings now being erected in Millbank which were over 100 feet high with a 400-ft. frontage. The original sketch design for those buildings was made on the back of an envelope only fifteen months ago. The contract ran into a very considerable sum of money. Caisson foundations were being used, which showed that English architects were not too far behind the times where conditions suited.

He hoped that if modified skyscrapers were permitted in this country where circumstances permitted the law regarding ancient lights would be adjusted; at present it was a great nuisance. He knew of a case where with one building that went up a huge crowd of officials with various instruments were occupied when the building was completed watching to see where the line of the sun at noon would strike a certain window-sill. If it had not been right the whole building might have had to come down.

MR. JOHN L. HODGSON said he had been struck by the lecturer's description of the skyscraper as "a skeleton on which the building hung." He thought it might be of interest to point out that, on the basis of this definition, the first of the skyscrapers was our own Crystal Palace, which was built nearly eighty years ago of glass panels fitting into an immense cast iron frame. The originator of this building was Sir Joseph Paxton, landscape gardener to the Duke of Devonshire. A picture, showing Paxton discussing with Prince Albert the plans of this building, adorned the wall of the staircase which led from the hall. Until quite recently there existed in the gardens of Chatsworth House in Derbyshire a large cast iron and glass conservatory which was Paxton's first attempt at skyscraper construction. This conservatory, which ushered in a new architectural epoch, and which should have been preserved as carefully as the early locomotives, or the first aeroplane that flew, was gleefully destroyed by a company of the Royal Engineers shortly after the war. They blew it up and distributed the glass over a large portion of Chatsworth Park.

One disadvantage of such huge buildings as the lecturer had shown was the extraordinary congestion of humanity which resulted and the lack of facilities for exercise, which led to a difficulty in preserving health. There was a great deal to be said for spreading out horizontally and letting each individual have his own piece of land with free access to both earth and sky. But this spreading should not be done in the planless and hideous fashion in which it was now being done in England.

The great ant-hills of Central Africa were in many ways similar to the skyscraper which the lecturer had described. They had their own heating, ventilation, and sanitary and water supply systems. The inhabitants, when they ventured outside them, usually constructed covered in passage ways to protect them from the weather (in their case the tremendous and desiccating heat) and from their hereditary enemies.

The lecturer had referred to the fact that a man might spend his office hours in the lower storeys of a skyscraper, his sleeping and recreation hours halfway up and his religious hours in the church which crowned and adorned the edifice. If at the termination of his activities his body was sent to the basement to be resolved into its constituent elements, the analogy to the ant-hill type of existence would be almost complete.

He hoped that mankind was not going to emulate the achievements and habits of the termites.

He thanked the lecturer for his brilliant and stimulating lecture.

SIR WILLIAM MACKENZIE, G.B.E., K.C., said that before hearing Mr. Bossom's lecture he had had no idea that American skyscrapers were such an immense success. He had been struck by the great convenience of the various buildings erected, and what the lecturer said as to the schedule of times within which the various pieces of work must be completed was very remarkable and must result in the cost of the building being greatly reduced.

He had heard it said that the trouble about building in England was the London Building Act, but that Act did not apply to Liverpool, Manchester, Leeds, and other provincial cities where one found the same stagnation as in London. The fact was that the London Building Act had not got much to do with it. What was wanted was a little more of that initiative and go which existed in the architectural profession in America. Without some such schedule as the lecturer had described not much progress could be made. The workmen wanted higher wages, and rightly so, but they were told that such wages could not be paid. The lecturer had shown how greater wages were paid in America while at the same time buildings were erected as cheaply as in this country. There was something radically different when America could afford to pay wages so very much higher than in this country while the cost of a building in the two countries was about the same.

MR. HUGH DAVIES said he had had the pleasure of hearing from the lecturer on many occasions an account of the methods adopted in America, and he was one of those who were endeavouring to ensure that some of those methods were applied in England. He thought the most interesting part of the paper was the indication of the extraordinary economic development of the building industry of the United States. There were those who suggested that this country should immediately adopt American methods throughout the building industry, and some of the objections to that such as the London Building Act had been mentioned that evening. There were, however other difficulties. In the first place, the building industry in this country was still undeveloped and in a primitive condition. It was an industry for the most part of small builders engaged on small buildings, builders who necessarily had a somewhat narrow outlook, employing a small number of technicians only; the industry was unfitted in its general constitution for carrying out work on an American scale. To secure a state of affairs in which it would be possible to pay wages as high as those paid in America a re-organisation of the building industry was needed and a re-arrangement of the methods by which the work was carried out.

The lecturer had already taken a step which indicated the new position he was seeking in the counsels of the nation; he had already approached the Board of Education with suggestions as to the manner in which there should be applied in English education the knowledge obtained by the experience of American architecture. He hoped the lecturer would be successful in his efforts, and that within a

generation instead of the best workmen in this country going across to America and there securing a better reward for their efforts, they would be able owing to the re-organisation of buildings on American lines to obtain that reward without leaving this country, making possible not only the payment of better wages but the production of results as delightfully artistic and refreshing as those the lecturer had illustrated.

THE CHAIRMAN, in proposing a hearty vote of thanks to Mr. Bossom for his paper, said that in London people liked to do things such as placing columns over glass, putting shirts and haberdashery on show in the windows of shops and erecting beside them columns as if the place was a temple; constructions which the Greeks never knew and the Romans never foresaw. There was much absurdity and nonsense going on in that way, but in America a new clean-cut expression was being evolved, and what Prof. Lethaby called fine building, with straightforward expression. If architects in this country would stop adding unnecessary things to structures greater business would result for them.

The vote of thanks was carried unanimously.

MR. BOSSOM, in reply, said there was always a great disadvantage in talking about skyscrapers, because one was taken as advocating them for London by so many people even in spite of most emphatic protest against it. Personally he thought skyscrapers were quite inappropriate in this country. When the Royal Institution of British Architects were considering what should be their attitude towards a proposal for allowing greater height for buildings in London some years ago, he crossed the ocean at considerable inconvenience to advocate strongly that the R.I.B.A. should oppose skyscrapers here. Skyscrapers were not wanted in this country, but we might gather some advantage from other experience.

On the motion of SIR DANIEL KEYMER, a hearty vote of thanks was accorded to the Chairman for presiding.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, JUNE 11..University of London, at King's College, Strand, W.C. 5.30 p.m. Prof. Dr. Edward L. Stevenson, "The Geography of the pre-Columbian Period."

TUESDAY, JUNE 12.. Asiatic Society, at Burlington House, Piccadilly, W. 4.30 p.m. Sir E. Denison Ross, "The Contribution of Hungary to Central Asian Studies with special reference to Csoma de Kőrös." Colonial Institute, at the Hotel Victoria, Northumberland Avenue, W.C. 8.30 p.m.
Quekett Microscopical Club, 11, Chandos Street, W. 7.30 p.m. Prof. Julian Huxley, "Some Problems of Animal Growth."

WEDNESDAY, JUNE 13..Geological Society, Burlington House, W. 5.30 p.m. Prof. G. B. Barbour, "A

Re-excavated Cretaceous Valley on the Mongolian Border": Mr. S. I. Tomkicoff, "The Volcanic Complex of Calton Hill (Derbyshire): a Petrological Study."

University of London, at King's College, Strand, W.C. 5.30 p.m. Prof. Dr. Edward L. Stevenson, "Christopher Columbus and the beginnings of Trans-Oceanic Discovery."

THURSDAY, JUNE 14..Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m. Captain Sir G. H. Wilkins, "The Arctic Flight."

Historical Society, 22, Russell Square, W.C. 5 p.m. Alexander Prize Essay.

Royal Society, Burlington House, W. 4.30 p.m.

FRIDAY, JUNE 15..University of London, at King's College, Strand, W.C. 5.30 p.m. Mr. Edward Bensley, "The Satires of Joseph Hall." (Lecture I.) 5.30 p.m. Mr. John Mavrogordato, "The Erotokritos."

5.30 p.m. Dr. H. Wildon Carr, "Some Problems in Metaphysics." (Lecture I.)

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

ANNUAL GENERAL MEETING

The Council hereby give notice that the One-hundred-and-seventy-fourth Annual General Meeting, for the purpose of receiving the Council's Report and the Financial Statement for 1927, and for the election of Officers, will be held, in accordance with the Bye-laws, on Wednesday, June 27th, at 4 p.m.

(By Order of the Council),

GEORGE KENNETH MENZIES,

Secretary.

INDIAN SECTION.

FRIDAY, JUNE 8th, 1928. SIR CHARLES C. McLEOD, Bt., in the Chair.

A paper entitled "The Port of Calcutta and its Post-War Development" was read by Mr. S. C. STUART-WILLIAMS, Chairman, Calcutta Port Commissioners. The paper and discussion will be published in the *Journal* at an early date.

FIFTH ANNUAL COMPETITION OF INDUSTRIAL DESIGNS.

The entries for this year's Competition have now been received and although it will not be possible to state the exact number of designs entered until they are received and classified, it is quite evident that there will be an increase of approximately 250 competitors and of about 1,000 designs on last year's figures of 745 competitors and 2,224 designs respectively. It is expected that about 150 designs will be entered for the Prizes offered by the Empire

Marketing Board for a shop window bill. There will be a very large entry of designs for Christmas Cards and Calendars for which valuable prizes have this year been offered for the first time, and in the Textile Section it is anticipated that the number of entries will be more than double that of 1927, when 487 designs were entered. The numbers of entries in the various other Sections of the Competition are also quite up to those of last year.

The judging of the designs and awarding of the various Scholarships and Prizes will take place in July, and the accepted designs will be on view at the Imperial Institute, South Kensington, S.W., from August 4th to September 1st, Sundays included.

It is interesting to note that offers of Prizes for designs in connexion with the Competition for 1929 have already been received from several important Companies, as well as from the authorities of a well-known seaside resort.

PROCEEDINGS OF THE SOCIETY.

TWENTIETH ORDINARY MEETING.

WEDNESDAY, MAY 2nd, 1928.

THE HON. SIR CHARLES PARSONS, O.M., K.C.B., LL.D., D.Sc., F.R.S.,
in the Chair.

THE CHAIRMAN, introducing the lecturer, said his friend Mr. Taylor was the head of a large optical instrument firm, Messrs. Taylor, Taylor & Hobson, who made the highest class of optical and scientific instruments of all kinds. He had always been struck by the very great ingenuity shown by Mr. Taylor in all new developments and in production. He attained the highest degree of accuracy in manufacture with the minimum of cost, which was, of course, the great problem before the whole industry at present.

Some years previously, the lecturer had been good enough to show him some of his Meccano optical instruments, and the ingenuity and application of scientific principles in making them with standard parts were wonderful. He had not realised as he now understood was the case, that the lecturer proposed to deal with very wide questions of standardisation in trade generally. When the lecturer shewed him these instruments, he had realised how useful they would be in educating the younger members of the community, directing their minds to optical questions. He supposed that the initial difficulty in getting the system introduced would be the capital expenditure involved in making all the tools, combined with the limited market. In the case of Meccano, there was a vast industry represented in which hundreds of millions of capital were invested, and Meccano parts were sold by all the great stores, such as the Army and Navy and Harrods, whereas in the optical industry he supposed there was only a million or two of capital invested,

The following paper was read :—

STANDARDISATION IN APPARATUS FOR SCIENCE TEACHING.

By WILLIAM TAYLOR.

The object of this lecture is to call attention to the advantages of applying standardisation to apparatus for teaching science, to define some of the things to be attained and some to be avoided in standardisation, and to illustrate these points by showing apparatus comprising a limited number of very simple standardised optical and mechanical elements with which a large number of optical instruments may be built up.

The advantages of standardisation lie in the economy and convenience of uniform and simplified practice. In order to display the advantages of standardisation generally, let us consider the familiar case of writing papers. Long usage has established in business offices a notepaper measuring 10 inches by 8 inches. The economy of using this one standard lies in the fact that the paper can be made in indefinite quantities with the practical certainty of a ready market, and can therefore be sold at a lower price and is more readily available than if it were made in a variety of sizes. The convenience of having one standard size lies in the fact that all of the many appliances for typewriting, copying, duplicating, and storing, and the envelopes for posting, are also standardised to suit the paper, and these again are more readily available and less expensive than they would otherwise be.

But a paper of this size is too large for many other purposes, and accordingly, nearly forty years ago, I standardised smaller papers for use in our business at Leicester, by continuous halving of the 10×8 notepaper; and so we have bound blocks of papers and a multiplicity of business forms of the sizes shown here, namely, 8×5 , 5×4 , $4 \times 2\frac{1}{2}$ inches, and these smaller sizes, as you can see, are obtained by continuous halving of the 10×8 paper without any waste.

But as yet nobody, I believe, manufactures blocks of paper in these standard sizes; at any rate, we have to get them made specially for us. Apparently the paper trade has not sufficient vision of the advantages of extending standardization to smaller business papers in this way. It is prepared to supply paper cut to any size whatever, and the customers pay for the waste.

The remedy for this, which is true national economic waste, lies chiefly with the makers and users of business papers, for none of us would welcome being compelled by law to write only on papers 10×8 , 8×5 , 5×4 , or $4 \times 2\frac{1}{2}$ inches, although a few of my otherwise scientific friends would, I believe, welcome it if Parliament compelled us to write on standardized papers measured in centimetres and not in inches!

Somewhat outside the sphere of business papers there are Brief, Foolscap, and small notepapers, and others, which are more or less standardized, but these are not related by any system such as that of halving, and to that extent are lacking in economy and convenience.

For some years Mr. Hoover, in the United States Department of Commerce, has been actively promoting what he terms "simplified practice," which is sane standardization, in the leading industries of that country. His work has effected a large economic saving and is contributing to the present prosperity of America.

The President of our Board of Trade is promoting a similar movement in this country, and all those manufacturers who, to serve the Great War, turned their factories from producing a variety of things, each in relatively small quantities, to the production of a few of those products in large quantities, and who found that their costs were reduced in many cases by as much as half, will recognize that simplification of practice is an important means of attaining low cost of production while maintaining high rates of wages; two things which are vitally necessary for this country at the present time. •

The promotion of simplified practice through standardisation is, properly considered, a branch of Applied Science, and it is appropriate that it should be studied by teachers of Science and applied to meet their difficulty of procuring, with a minimum of expense and delay, apparatus for the teaching of Science.

In setting up simplified standards of practice, it must be borne in mind that, as the psychologists tell us, one of the most difficult things in the world is to change people's habits; and this is particularly difficult in old countries like our own. It is over a hundred years since France, as part of her great Revolution, started to establish by law the metric system of weights and measures; but that system has not, even yet, displaced all the old standards of measurement in use in France among the common people.

A metric system of screw threads has long been established as the national standard in Germany, but just before the War I purchased one of the leading German motor-cars and found that all the bolts had Whitworth screw threads based on the inch, and these were wedded to bolts whose diameters were based on the millimetre. This anomaly involved considerable inconvenience and cost, for the bolts had to be turned down specially to receive the Whitworth threads. Here is an ordinary illustration of the extreme difficulty of replacing an old standard by a new one. The result of trying to do so is generally not to simplify practice, but to make it more complex and wasteful. That, for example, would be the effect in our industries, and in many of the practical affairs of life, if we attempted to force on this country the adoption of the metric system of weights and measures.

The only way in which an old standard can be successfully replaced is to make the new standard much more attractive in use. In 1881 the Royal Photographic Society appointed a series of standards for the screw threads by which lenses were to be attached to cameras; but for many years these standards were not adopted by the lens-makers generally, because of the inconvenience and cost of making the change, and because, to the photographer, one screw was about

as good as another. When my firm began at Leicester, in 1887, to make photographic lenses, we adopted the Royal Photographic Society's Standards, and by making screws really interchangeable, and especially by the improvement made in starting the threads abruptly, so that they could not be crossed, and in making them so that the lenses always screwed home in the cameras with their index scales in one place, we made the Royal Photographic Society screws so much more attractive than other screws, that they gradually displaced the others and came into general use. It is only by giving a new Standard some such outstanding superiority in use that you can hope to replace an old one.

Because of the difficulty of uprooting old standards, it is frequently prudent, and therefore scientific, to preserve the old ones in spite of their not being ideally perfect. For example, it would be foolish to attempt to-day to upset the practice of using 10×8 inch notepaper in business unless we could provide paper of some other size, at far less cost, or otherwise much more attractive. And yet, from one point of view, 10×8 is not an ideal ratio of length to width, because when you cut 10×8 into two and get 8×5 , the ratio is changed. The only basis on which we could maintain a constant proportion under these circum-

stances is to make the ratio $\frac{\sqrt{2}}{1}$ or approximately $\frac{14}{10}$. That is an ideal

proportion which might perhaps be applied in the window glass trade, where, I believe, no very definite standards are yet adopted, and where there is enormous waste in cutting.

When standards are required for the dimensions of a series of articles of like kind, but differing in size, the number of standards should be a minimum. In every such case the advantages of standardization are inversely as the number of standards. Over-standardization is mere systemization, and may be worse than no standardization at all.

In order that the number of standards in any series shall be a minimum, it is generally desirable to arrange them in approximately geometrical progression and not in arithmetical progression. Here are two series of papers illustrating respectively arithmetical and geometrical progression. In the arithmetical series the papers increase successively in size by one-half inch each way. In the geometrical series, the first increase of area is equal to one-half inch each way, but it is made by doubling the area of the paper, and this system of doubling is applied successively right through the series. On looking at the arithmetical series, you will observe that while the difference of area between the two smallest members is substantial, that between the two largest is insignificant from any practical point of view. In the arithmetical series are 25 members. In the geometrical series, covering the same range, there are only 8 members. Whether it is for paper, or panes of glass, butter or rice, or shafts or bolts for machinery, or lenses or other elements of scientific apparatus, the need for geometrical series holds true, and for this reason it is a great virtue

of our sometimes despised systems of weights and measures, that they provide what we need for so many of the practical affairs of life, *viz.*, various geometrical series of units which we cannot find under a decimal system. This is the virtue, for example, of our 16 ounces to the pound and of our division of the inch into halves, quarters, eighths, sixteenths and so on. That geometrical progression is a virtue is the common experience of all people everywhere, for even in those countries where decimal systems of weights and measures prevail, the people still resort, with some difficulty, to dividing things into halves and quarters and eighths.

Of course, binary sub-division is only one way of obtaining a geometrical series, but it is the most convenient way in the case of all things which have to be cut without waste to a series of standards. The steps in such a series may be too large, and in such a case a series of intermediates related by doubling but with a different base may be introduced. Alternatively a series of standards may be based on some factor less than 2 although this would involve waste in cutting. There is more probability, however, that the figures derived in this way will not be whole numbers, and it is then desirable to appoint the nearest whole numbers, in spite of the fact that in doing so we depart from a strict formula.

Another way of obtaining an approximately geometrical series is to take a series of numbers such as 4, 5, 6, which may represent any convenient unit, and multiply each of these by two continuously to form a series such as 4, 5, 6, 8, 10, 12, 16, 20, 24, and so on.

In many standards the question of *interchangeability* is involved, as it is in the case of business notepapers, for the 10×8 notepaper must go interchangeably into the various typewriters, duplicating and copying machines, the envelopes in which the letters are posted, and the filing cabinets in which they are stored.

Sir Joseph Whitworth was our great pioneer in determining the principles on which interchangeability should be effected, and his principle was that the interior member (in this case the notepaper) should never exceed its nominal dimensions (although it might be somewhat smaller), while the exterior member for example the filing cabinet, should never be less than the nominal dimensions, and should preferably be substantially larger in order to facilitate getting the papers in and out. Subject to this limitation that neither part should overstep the common boundary or a neutral territory, the parts should be permitted to vary in their dimensions just so much, but only so much, as is necessary to accommodate ordinary and inevitable errors of workmanship. For example, we might say that our 10×8 notepaper should never exceed 10 inches in length nor 8 inches in width, but that it might be as much as $1/16$ inch short in either dimension; also, that the cabinet should never be less than $10\frac{1}{2}$ inches by $8\frac{1}{2}$ inches, but might exceed either of these dimensions by $\frac{1}{8}$ inch. This is a very rough general statement and illustration

of the first principles underlying interchangeable manufacture, whether of notepaper, filing cabinets, the parts of machines, or scientific apparatus, or of anything else.

The question is often asked, "*Does not standardisation hamper progress?*" and the answer is that it depends on what and how we standardise. In the case of our notepaper we wisely standardise its overall dimensions, but we should probably be unwise to standardise the thickness, colour, or the quality of surface of the paper. Some years ago I served on a Committee which standardised wrenches for bolts and nuts. Quite properly we standardised the gaps in the wrenches so as to ensure that they would always engage the heads of the bolts, although, on the mistaken principle that a close fit was a good fit, we made them fit too closely. But the Committee went further and made the mistake of standardising the entire outer form of the wrench. The outer form is not concerned in interchangeability and should quite properly vary for different conditions and with different materials. For example, the bulk of material in the wrench can be greatly reduced when certain alloy steels, such as Vanadium steel, are employed.

It is only when standardisation is misapplied, or where it is overdone so that it becomes mere systemisation, or where it is done empirically, without proper knowledge based on experience, that it hampers progress.

It is true that every standard, once established, is difficult to change and introduces a certain inertia into practice, but the advantages gained by sound standardisation outweigh the disadvantages; and all this may be illustrated by the familiar case of the Ford car. Mr. Ford standardised his first car many years ago, and except that he has continuously improved his materials and minor points of design, he has maintained his general standards for dimensions, and even standards of form, unaltered through many years. This persistent adherence to standards has obviously been a source of great economy and convenience to Mr. Ford and his millions of customers. Nevertheless, Mr. Ford has himself at last had to make progress by abandoning some of those standards and substituting fresh ones, but certain standards he has retained because they did not hamper progress, and among these are his standards of measurement based on the inch, standards for screw threads, the hexagon heads of bolts, wrenches, ball bearings and other elements and components. This example shows that the things which we can most safely and permanently standardise are not the complete machines or instruments, but basic measurements, and the dimensions of elements or components, whether of machines, scientific apparatus or similar things.

Those of us who during the Great War had to manufacture instruments for gunnery, telescopes, sights, range-finders, directors, clinometers and so forth, were greatly hampered by the lack of standardisation. This lack cost the country enormous sums of money, delay in procuring the supplies, and loss of life through the lack of them in the field. Toward the end of the War a

Committee on Glass and Optical Instruments was formed under the Department of Scientific and Industrial Research, and under the chairmanship of Sir Herbert Jackson, on whose request I acted as Chairman of the section on Optical Instruments, and on that section we turned attention to standardisation in apparatus, and especially in optical apparatus used in the fighting services. With the co-operation of the services and the leading manufacturers, we reviewed the subject and found that there was very little in common among the designs of the many different instruments, most of which were much as the original independent inventors had planned them, and few of which had ever been considered from the point of view of manufacturing in quantities. Practically all required, for their making, a very considerable number of special tools, when, if the elements of design had been standardised, standard tools could have been used. By standard tools I mean instruments of standard sizes, available in most tool shops, such as drills, reamers, milling cutters, and so on.

Among other matters we reviewed the subject of the objective lenses for telescopes of all kinds. In the designs of one of the Services alone we found that there were embodied objectives of more than 200 different focal lengths. After full consideration it was agreed that we could cover practically the whole of this field by using some 17 focal lengths which we standardised in approximate geometrical progression ranging from $2\frac{1}{2}$ to 40 inches. In the same way we dealt with a variety of similar standards.*

While this work was going on, it became clear that what we were doing was to analyse the whole field of optical instruments used in warfare, reducing these instruments as far as possible to their simplest common elements, and standardising these common elements so that in future new designs might be built from them as far as possible synthetically. This provides that in time of urgent need such elements can be manufactured in correspondingly larger numbers of each size, and therefore in substantially less time and at substantially lower cost, and they could be made for stock with the certainty that they would find use in some of the various designs in which they are embodied.

At that time Professor Cheshire suggested to me that a kind of glorified optical bench might be constructed of such elements, applicable to illustrating the principles of optical instruments in general, for the purpose of teaching in schools. Later, when I turned attention, with the help of Mr. Warmisham and others of our staff, to a wider development of the idea, we produced the apparatus which I have the pleasure of showing you this evening as an illustration of what may be done by applying standardisation in apparatus for the teaching of science.

In order that such apparatus may be available everywhere at a minimum cost, this is made of the simplest materials. It has no expensive finish such as we are accustomed to find on most present-day optical instruments, and many

* Report of the Inquiry Committee on the Standardisation of the elements of Optical Instruments. 1920. H.M. Stationery Office. Price 1/-.

of those who see it may condemn it as a toy, just as in its early days the Kodak was condemned ; but this apparatus was designed with the view that only in this way could it be made available to everyone in the same degree as the Kodak is available. This apparatus is constructed from a series of seven standardised lenses, one prism, four slips of glass, three mirrors, a plain and a ground glass (these comprising the optical elements) and a few standardised mechanical elements mainly constructed as stampings of sheet steel and treated by a rustproofing process. The instruments exhibited are built out of these standard elements and comprise :—

Magnifiers with powers of 2, 5, 7, 9 and 12.

Compound Microscopes of powers 10, 35, 75, 150.

Telescopes X6, X15, X33, X55, the last of which is an astronomical telescope with a finder, equatorial mounting, and fine adjustments.

A simple Microscope.

A Kaleidoscope.

A Tele-kaleidoscope.

A Photometer.

A Magic Image.

A Garden Microscope X7.

Binoculars X3.

A Detective Telescope.

Periscopes. A Stereoscope.

A Level.

A Periscopic Telescope.

A Theodolite.

A Heliograph.

A Rangefinder.

A Spectroscope.

Among the optical elements there are two standard plano-convex lenses, one of 1.75 inch focal length and one of 7 inches. By combining two of the former we get a focal length of about 1 inch, and by combining two of the 7 inch lenses we get a combination with a focal length of about $3\frac{1}{2}$ inches. In this simple way is provided a series of lenses of four focal lengths in approximate geometrical progression. This series is extended in one direction by the addition of an achromatic lens of 40 inches focal length and in the other direction by properly corrected microscope objectives of focal lengths 1.25, .62, and .31 inch. The outer diameters of these lenses are standardised to fit in the mountings which I shall describe presently, and in the case of the simplest of these elements, a convenient and inexpensive way of providing them with protecting rims of standard size has been found in die-casting an alloy directly on the glass.

The mechanical elements which serve to hold the optical elements in various combinations and relationships have been standardised according to their function. In most optical instruments a tube is provided for shielding the

optical elements from stray light and holding them in correct alignment and at correct distances apart. Generally such tubes are screwed to receive cells containing the lenses. But screw threads are expensive things to make, and they do not lend themselves readily to varying the separations of the optical elements, as is necessary in apparatus of the present kind. Accordingly, screws are dispensed with, and reliance is placed on cylindrical fittings for both holding and centring the lenses. There are two standard tubes or sheaths for holding lenses, one having a cylindrical bore of a standard inch, and the other of two inches. The former, which you will see represented in many of the instruments here, is made in the simplest possible way by bending a sheet metal stamping round an accurate shaft and spot welding the overlapping edges at two points some little way from the ends. This leaves the ends of the tube somewhat elastic so that they hold, by friction, eyepieces and other elements which may be placed in them. A standard eyecup is provided, with a cylindrical tubular body of the standard 1 inch outer diameter, and this slips into the 1 inch tube and fits nicely so as to facilitate adjustment, as in focussing. Two standard cylindrical tubular pieces of different lengths, termed "liners," are provided, either of which may be used for holding lenses in the other end of the sheath. These also are made from sheet steel stampings and are formed in dies, so that they slide nicely in the main sheath for focussing or adjustment. Any of the plano-convex lenses may be dropped into the eyecup, or into one of these liners, against shoulders which are provided, and may be held therein by sliding after them a ring with three elastic arms adapted to hold frictionally in the liner or eyecup. Spacers of two standard lengths, again made from sheet steel, are used for spacing combinations of these lenses. A union is provided for holding two or more standard sheaths together in alignment. With these very simple mechanical elements, the following may be built:—

Magnifiers with powers of 2, 5, 7, 9 and 12.

A Compound Microscope of power 10.

An instrument which Mr. Warmisham has termed "the Garden Microscope," of power X7, with which naturalists may, without disturbing the insects, watch many things, such as the bee gathering honey and the spider catching and trussing the fly.

There is a telescope of X6 magnification, which would please the boy scout, and an erecting telescope of X15.

Here are the elements of a camera—the lens and the focussing screen, and means for taking little blue print pictures. By the addition of three sheet steel stampings bent to form 60° channels, and three slips of common glass, we can build up a Kaleidoscope and a novel instrument which Mr. Warmisham calls a Tele-kaleidoscope, which multiplies and sets into geometrical patterns anything to which you direct it—the faces of your friends, flowers, passing vehicles, and so on, and glorifies even insignificant objects.

Alternatively, we may add a simple negative lens and make a Galilean opera telescope X3, or one of X6, and by the further addition of two simple sheet steel stampings, we get a binocular opera glass.

All these are instruments adapted to be held in the hand.

In order to furnish means for holding such instruments rigidly or adjustably, we may take the three channels which form part of the Kaleidoscopes, and by adding a sheet steel triangular top, and by the use of that admirable invention of Mr. Hornby's embodied in Meccano, that is by piercing our pieces with holes, (which, as in his case, are spaced at distances of $\frac{1}{2}$ inch, or multiples thereof), and providing some simple standard screws and nuts, we form a tripod stand, which, considering the primitive nature of the material, is wonderfully rigid. Then we add a right-angle bracket, which will reappear in many of the instruments exhibited, and which is pierced with Mr. Hornby's system of holes, while one limb is formed with a circular edge around a central hole; and then with a simple sheet metal saddle and a girth, we can build up universal mountings for any of our little instruments.

Primitive as these parts are, their designs embody sound principles. The tripod stands stably on three feet. Its limbs are adapted to sustain end-wise compression and to resist bending. The edges which are under tension are made straight. The bracket is supported stably on three points at the top of the tripod. The saddle is formed to support the tube stably at four points with the girth urging it equally to all of these, and the combination is made friction-tight as it moves around the circular edge of the bracket, and is made stable by bearing on the bracket at three points. Thus, while this apparatus is intended primarily for illustration of the science of optics, it may be used (as, indeed, all school apparatus should be devised) to exemplify sound principles of design in mechanics.

By re-arranging the parts of this universal mounting and substituting for the girth a phosphor bronze spring, we have means of moving any of our instruments longitudinally as for the purpose of focussing, and here is our X10 microscope, so mounted that it may be placed over a cardboard box covered with a piece of glass and used for the temporary imprisonment of those little creatures which all young people and many old ones delight to watch.

Now, by adding a stage element and a pair of phosphor bronze clips, we can build the frame of a simple microscope in which we may place and adjust quite nicely any of the simple magnifiers with powers 2, 5, 7, 9 or 12.

With the primitive parts already described, one may, as with Meccano, make an almost indefinite series of combinations, and here is another which I show because it illustrates the prevailing need of education in science.

I was asked to exhibit this apparatus in a foreign country (which I will not name), and in one of the largest cities in the world the leading optician came to see it. (By the leading "optician" I mean a polished gentleman accustomed to selling spectacles, telescopes, opera glasses, and optical apparatus generally).

I showed him this knitting needle supported upright in a cotton reel, and a peep-hole through which he was to look at the top of the needle. On the needle he saw a little devil, and he rubbed his eyes and looked again! Then he went to the needle and blew it, and looked once more! Then he went back and tried to pinch the devil off the point of the needle, but he found it was still there, and this puzzled him completely until I showed him the original devil on a piece of paper, and how an image of it could be formed on the top of the needle by means of this lens!

But, to return: Here are two mirrors to be added to our series of optical elements. There is another one to be shown later, and the three form a series obtained without waste by successive halving. Each mirror is sheathed in a little steel stamping. It is held geometrically at three points by pressure of a spring, and I would observe that while such a system of mounting is ideally perfect, it is attained at a cost which is probably no greater than it would be if it lacked these merits. There are also two little sheet steel brackets pierced with holes by which one of the mirrors may be held in alternative positions at 45° rigidly, or at other angles adjustably.

These elements, together with the saddles and girths already described, provide means for building up this small periscope (which may be extended to indefinite length by the addition of more sheaths), a telescope with a mirror to turn the view at right angles, with which a scout may observe his distant enemy while hiding behind a tree; a periscopic telescope; a reflecting level, and a stereoscope with adjustments for focussing and for the inter-ocular separation.

I have hitherto described rather primitive apparatus made from very simple elements. It is now possible, by adding a very few more standard elements, to provide more elaborate apparatus; and having, as I hope, excited your interest in this subject, I will describe the other elements rather more systematically on the basis of their functions.

In the majority of scientific apparatus, whether optical or otherwise, we need supporting stands. Here is a stand made of simple materials, which may be used on a table, or may be attached interchangeably to one of the tripods standing on the floor. The table stand comprises a circular column of standard one inch outer diameter, made of sheet metal, and three stamped sheet steel legs, of one pattern, attached to it radially by means of six screws and nuts. The tubular column is curled over wire rings at its ends to enable it to resist torsion. It is pierced with screw holes at one-inch intervals on opposite sides, and has an aperture through which one's fingers may be inserted for putting the nuts and screws together, and for other purposes. The radial feet are channelled to resist bending, and the lower edge, which is in tension, is made straight to give maximum rigidity. The toes are formed so that they will not scratch the table, and they are pierced with holes so that they may, when necessary, be fastened down.

The tripod stand, for standing on the floor, is also simple. The three pairs of wooden sticks are united by stamped steel joint pieces.

The table stand fits the triangular head of the tripod stand and is attachable to it close to the three junction points of the sticks, to secure rigidity.

In order to provide a more refined means of moving a sheath with its contents longitudinally, for focussing, as in a microscope, a cradle is provided of sheet steel having two pairs of bearing points in which, as in crutches, the sheath may lie. A wire spring is provided to hold the sheath equally against these four points of bearing, and those who examine this apparatus will probably be impressed by the facility with which coarse and fine motions may be obtained by this simple means, the coarse motion by sliding the sheath, and the fine motion by rotating it in the cradle with slight end-wise pressure. This device (which many may think primitive) has this virtue not possessed by the usual more expensive devices, that it does not demand fine workmanship and maintains its nice fit without shake in spite of wear. This cradle, like the other elements to be described, is provided with Mr. Hornby's perforations to facilitate attachment in various ways.

In order to provide means by which an instrument may be rotated about an axis, pairs of circular steel stampings are provided, connected by screws, so that one stamping is rotatable on the other and remains held by any desired friction.

In order to measure the angle of movement upon any such swivel, a disc graduated in degrees is provided to be interposed between the swivels, and a vernier scale attachable to one of them. The graduated disc may be set and remains held frictionally so as to start its reading from zero in any position of the swivel.

In order to provide means for fine adjustment of the rotation of the swivels, a three-armed star of sheet steel is provided and placed between the swivels, and a device, including a tangential screw and spring, is provided for turning the three-armed star adjustably in relation to one of the swivels so as to move the other one. A combination of these parts may be made to form a swivel which may be moved by hand quickly through any angle and finely adjusted by means of the screw.

In addition two brackets are provided, one formed rigidly at right angles, and the other adjustable as to angle.

Composed of these standardised elements, we have here a vertical microscope which may be used for magnifications of 10, 35, 75, or 150 diameters. It is now fitted for a magnification of 35, with an adjustable mirror below the stage, and a fitting which will carry either a condensing lens, or a plain glass for use as a vertical illuminator. For this latter purpose an ordinary flash lamp may be placed in the column of the stand to throw light through the lateral aperture. By adding a pair of the standard swivels and duplicating the column of the stand, we get an inclinable microscope of similar capacity, and in this case it

is fitted for a magnification of 75 diameters. When set horizontally, the device shown in the vertical microscope as forming a vertical illuminator may be used to form a camera lucida. In another inclinable microscope, which is fitted for a magnification of 150 diameters, standard lenses are fitted below the stage with a suitable diaphragm to form a dark field illuminator, and those who examine later, by the aid of this instrument, the diatoms which have been set in it, will, I think, be surprised at the results which may be obtained with these simple appliances.

Here is an erecting telescope of power 15, on a stand, with universal adjustments. The fine adjustments I have described could be added by anyone.

Here is a larger telescope with a power X55, mounted with the fine adjustments.

Here is a smaller telescope, with cross wires in the eyepiece, mounted for use as a theodolite.

Here is a sextant, and here a rangefinder.

Here is a new form of heliograph, devised with the view of providing an instrument which the boy scout might use. It contains two objective lenses in whose axes (which are in parallel planes) are mirrors set so as to reflect the light at right angles to a common focal point in a diaphragm at the centre of a swivel between the planes. It being known where the distant observer is stationed, one of the lenses is turned toward him so that his station can be seen in the diaphragm. The other lens is then turned toward the sun; it forms an image of the sun in the diaphragm, and this acts as the source of light from which the other lens projects the light in a parallel beam toward the distant station.

Here is a spectroscope, and here the last of the instruments I have brought to show you—a X55 astronomical telescope with a finder, and universal mountings, one axis of which is inclinable for equatorial mounting—and of this telescope Professor Cheshire has remarked that it is a much better instrument than Galileo had when he made his great discoveries. With this simple apparatus our youths might observe the apparent motion of the stars, the mountains in the moon, the rings of Saturn, and the satellites of Jupiter, things about which to-day most people have read, but which few have seen.

Some of my friends who know that I have for most of my life been associated with precision work of a very different kind, wonder that I should spend my time on primitive apparatus such as I have shown you. But I make no apology. While these models were being developed I found great pleasure in the thought that we might be laying the foundation for the better education of the next generation in the principles and use of optical apparatus. These models are largely made by hand and are not in all points so perfect as they might otherwise be, but they indicate the way in which standardisation might be applied with advantage in other apparatus for teaching, when standardisation is viewed as simplification of practice based on analysis of the functions of the various

elements necessary in a variety of such apparatus. It would go far to reduce the cost to teachers and to schools of scientific apparatus if it could be provided in the form of simple standardised elements, not necessarily assembled in the factories, but supplied as Meccano is supplied, in a form in which the students could readily assemble them and re-assemble them in different combinations for different purposes.

But I was inspired in developing this apparatus by the further idea that, while it might be useful in schools, it might find a far larger use among boys and girls in their homes, in their studies, and as a delightful hobby.

Whether these visions will be realised by me I cannot tell. I feel like Mr. Edison must have felt when he had developed a scheme for making standardised houses by pouring concrete into steel moulds in which the bath tubs, the water and gas pipes, and the electric wires were already placed. It was a great idea which he set aside in order to develop his storage battery. In the same way I find myself busy with other things, and hope that you will not disturb my scanty leisure by asking me at what price these things can be supplied and when they can be delivered. The tools are not made, and this apparatus has been taken from a trunk to be shown to you. What is yet lacking is men who can share my vision and lend a hand to realise it.

When I showed this apparatus some time ago to Sir Charles Parsons, who is interested in everything of the kind, and is, as you know, a very busy man, he dropped his work for a large part of a day, lit his pipe, and sat down to enjoy my vision. That is why he is here to-night, and I have to thank him for introducing me as a lecturer to this Society and for encouraging me by his presence.

DISCUSSION.

The CHAIRMAN said it would be agreed that Mr. Taylor was not only a conjuror, but a great applier of science to industry, and a great artist. It was much more difficult to accomplish great works in steel and brass than to be a fashionable painter—at least, so an engineer would say!

PROFESSOR F. J. CHESHIRE, C.B.E., F.Inst.P., said that the subject which had been introduced by the lecturer might be looked upon from several points of view. It was of great interest academically, but its chief interest was probably that of technical production. He (the speaker) had been brought into very close contact with the subject of standardisation in the early days of the war at the Ministry of Munitions. The work of producing supplies was made one of the very greatest difficulty by the fact that the question of standardisation had never been threshed out for the bulk of optical munitions of war. What had happened before the war was that, if twenty rangefinders, say, were required by one of the Services, the order for twenty was not given to one firm, but was split up amongst four, say, each getting an order for five instruments only. This policy of splitting-up orders was probably adopted deliberately, under the mistaken idea that in the event of war a larger number of manufacturers would be available in knowledge

and equipment for the production of any given munition. What actually happened was this. Since no manufacturer ever received an order for a sufficient number of a given type of optical munitions to justify him in making up the necessary expensive tools and jigs to allow of economic production by means of interchangeable parts, he had, in pre-war days, to resort to toolroom production. The result was calamitous. When the war brought a demand for enormous numbers of these munitions it could not be met. There was hardly an instrument in existence which had been designed for mass production, and before it was possible to get to work to turn out those munitions seriously, practically every instrument had to be gone through and re-designed for the purpose of mass production. It would thus be seen how important it was that the question of standardisation should receive attention. It had received attention then, and it still required to receive attention to-day.

The Sub-Committee, of which the lecturer was the Chairman, had issued what he considered to be a very valuable report on the subject, but he had never seen it on a bookstall or anywhere except on his own bookshelf. It could be bought for sixpence, and he would strongly advise all those who were interested in this question of standardisation to obtain a copy.

It was mainly, however, from the educational point of view that he was interested in the subject. The lecturer had proved to the hilt that the adoption of methods of standardisation made it possible to produce a class of optical instrument which could be introduced into every village in the kingdom, and it was in this that he was mainly interested. What he wanted to see was a higher optical education of the man in the street. But one could not start with the man in the street: one must start with the boy in the school, and even with the boy in the home, because if a boy was to use any of these instruments with value and interest to himself, he must be educated up to the point at which it was no longer a task, but a pleasure and a joy to use them. The boy should be taught to go to the village-pond with a pickle-bottle and fill it with material for his simple microscope, and then go home and revel in it. He was quite certain that that could be done. A boy could easily be taught, and if furnished with simple apparatus, he believed he would be extraordinarily interested in natural history. A year or two previously he had had an amusing experience in this regard. He was living in the country, and his apples were disappearing with woeful regularity, and, of course, he more than suspected what was happening. Eventually he was supplied with the names of the suspects, and it was a question of what he should do. Considering that the boys were simply doing to his apples what used to be done to his neighbour's apples when he was a boy, he could not view the matter very seriously, so after thinking the matter over he had got a few very simple objects and his microscope, and had invited all the boys to spend an afternoon with the microscope. They had come with fear and trembling, and when he had looked out of the window, he saw over the hedge rows of heads belonging to anxious mothers. However, they had settled down to the microscope, and had gone through a dozen or so of the common objects of the countryside. The interest taken by the boys in those objects was amazing. Unfortunately, he had not been able to supply them with such a microscope as the lecturer would now be able to supply, but the net result was that he had given the boys some little instruction on how to collect objects for the microscope, and the boys at once formed themselves into a little brotherhood to collect material for him; and more than that, as they were going away from the house, he had said, "By the bye, evidently some very bad boys have been stealing my apples. I wish you would just look out for them, and if you see anybody stealing my apples,

just tell them what you think about them, and let me know." He did not believe a single apple had disappeared after that, and he was supplied with material for a considerable time.

Perhaps the most interesting experience he had had with the boys was in connection with the telescope which was exhibited at that meeting. Some years ago he had come to the conclusion that a better telescope than Galileo ever possessed could be built for one shilling. With that object in view, he had written to various places in Italy for the purpose of getting the constructional data for a reproduction of Galileo's telescope. After some considerable trouble he was referred to the catalogue of the Loan Exhibition at Kensington in 1876, where he got everything he wanted. As he had suspected, by means of postal tubes and a couple of lenses he did make a better telescope than Galileo ever possessed at a cost of one shilling.

SIR HERBERT JACKSON, K.B.E., F.R.S., said the lecturer had done a service, which was probably greater than would appear at first sight, because the danger of over-standardisation was known to everybody, and the lecturer was the finest exponent he knew of standardisation which was productive of progress rather than inimical to progress. He liked very much the lecturer's old definition that the real standardisation was that which was not degraded into mere systematisation. That was the danger of all standardisation.

The lecturer did not seem very optimistic about the future of the valuable collection of apparatus he had shown, but he did not know that there was any reason for lack of optimism. In his own boyhood there was a telescope and a microscope in every well-constituted house. He hoped that day was coming again, and that the inspiring and elevating character of the studies that could be made with optical apparatus would be recognised again. Then the lecturer would be recognised to be what he truly was in his own bigger work at Leicester—a benefactor of mankind.

Not the least important of the lecturer's inventions was the one referred to early in the lecture—the excellent photographic lens flange, which enabled one to put lens after lens on to the same flange, and did away with the necessity of going down on one's knees to read the figuring of the iris diaphragm. He wished to be allowed to offer his heartiest congratulations to the lecturer, and the best possible wishes for the success of his notable inventions.

Dr. REGINALD S. CLAY (Principal, Northern Polytechnic), expressed the hope that the instruments shown would be successfully placed on the market. It would be valuable for teaching purposes if schools could buy the apparatus, so that everyone might have the opportunity of learning by actual experiment what a microscope, a telescope and other instruments consisted of. Knowing the interest the lecturer had always taken in the matter of standardisation, he had written to him on the question of standardising projection apparatus for teaching purposes. At the Northern Polytechnic they had ten or twelve lanterns, and he did not think any one of the lenses could be taken out of one lantern and put into any other. There was no reason why there should not be a series of standard sizes adopted for projection apparatus, as had already been done in connection with the kinematograph, and he thought it was only a matter of bringing the manufacturers together and exerting a little pressure upon them from the scientific teachers throughout the country, to get a more useful instrument for teaching purposes. He hoped that, with the help of the lecturer and of the Electrical Engineering Standards Committee, it might be possible to get something done in that direction.

Mr. CONRAD BECK, C.B.E. (Vice-Chairman, British Scientific Instrument Research Association), said he had feared that the lecturer would raise the question of the standardisation of higher-class teaching apparatus, and he had had an unpleasant vision of standardised teaching, standardised science, standardised painting and sculpture. After hearing the lecture, he had realised that the standardisation suggested could not do harm. He wondered whether it was not conceivable to induce the teaching authorities to place an order of sufficient size to justify the making of the necessary tools.

Mr. R. S. WHIPPLE (Cambridge Instrument Company), congratulated the lecturer on the beautiful geometrical design he had put into many of the instruments he had exhibited. He hoped, with Mr. Beck, that it would be possible for some of the education authorities to arrange to order the instruments in sufficient number to justify the making of the tools. With regard to electrical instruments, great credit was due to Mr. Paul for his valuable work in standardising galvanometers and the accessories used with them. He saw no reason why it should not be possible to standardise scientific teaching apparatus, in view of the progress in standardisation already made, not only in the motor industry, but in the manufacture of small pieces of apparatus for chemists.

Mr. R. W. PAUL said he was glad to have an opportunity of thanking the lecturer for showing the beautiful results of his "devilish ingenuity," as an American physicist described it. He hoped he would be able to overcome the difficulties which arose when one tried to convert science teachers to the use of any apparatus which did not exactly fit in with their individual preferences. He remembered in the early days of the National Physical Laboratory the difficulty of replacing even simple things like resistance box plugs, for if one of these was lost a new one had had to be made specially. Some years ago the British Instrument Research Association had called together some representatives of the associations of science teachers with a view to obtaining their collaboration in producing a standard set of apparatus for teaching elementary physics, but they had failed to collaborate in carrying out the idea. The outlook of the teacher was different from that of the manufacturer. The British Engineering Standards Association had done a great deal of work in standardisation in engineering, but the subject of the lecture appeared to be a little outside their scope, unless the science teachers could meet together and agree on some kind of a schedule as to what they really required.

Mr. C. LE MAISTRE (Secretary, British Engineering Standards Association), said the discussion reminded him of the story of three oil experts returning from the West coast of Africa, two Americans and one Englishman. The two Americans talked of oil night after night in the smoking room, until the Englishman could sit there no longer. At last he said, "I am interested in oil, gentlemen. I am Mr. Jones." "Not *the* Mr. Jones, the expert?" "Yes." To which the American replied, "Good Lord, and to think I had never heard of him!" The B.E.S.A. had been in existence for twenty-seven years, and judging by the discussion there seemed to be hardly anybody who knew of the existence of the B.E.S.A., an absolutely impartial organisation to which the teachers, through their organisations, could apply, and where they could get collective effort and collective results. The value of standardisation was not being brought before the teachers, and he hoped the lecturer would be the pioneer who would bring it before them.

He greatly admired the lecturer's diagram showing the superiority of geometrical over arithmetical progression. The efforts of the French, the Germans, and even the Americans to foist upon Britain scientific methods based on the lamentable metric system must be frustrated. If he had known that the lecturer was going to show the interesting and simple example of standardised paper, he would have brought an example of the German simplification, because while it was extremely good it showed the difficulties in which the metric system had placed the German manufacturer.

MR. G. F. O'RIORDAN (Principal, Battersea Polytechnic), said that the views of the teacher had changed very much of late, and he was now a much more practical man than he used to be. Knowing the lecturer to be a benefactor of mankind, he was quite convinced that he would also prove to be a benefactor of science teachers. There were several members of the Board of Education present, and those members were not, as had been suggested, solely interested in finance; they were in very intimate contact with every member of the teaching profession, and he thought a great deal could be done through a meeting of members of the Board, inspectors, and leading members of the L.C.C. Education Department. The suggestions put forward by the lecturer were full of possibilities, as bringing within the grasp of the teacher apparatus which, owing to its high cost, could not possibly have been seriously considered before.

Professor CHARLES R. DARLING said that as one of those ignorant teachers he was filled with admiration for the ingenuity shown by Mr. Taylor in the construction of his apparatus; but any good teacher must ask himself whether, by the aid of the apparatus shown, he could teach to better advantage than he did at present. He was not quite sure whether, with the apparatus shown, he would get better results than by his present methods. Unless that could be demonstrated, it was not to be expected that teachers would adopt the new apparatus. After all, a teacher who was teaching optics wished to turn out his students with the maximum amount of knowledge, and he, therefore, chose the apparatus which he thought would secure that end, and he thought this was the proper point of view from which to regard the matter. From the other point of view, that of teaching optics to the man in the street and the boy in the home, as a kind of hobby like the use of Meccano, he could see a wonderful application of the lecturer's apparatus. He was not prepared to say off-hand, however, whether it would be better for teaching in the schools than the apparatus at present employed. He wished to assure those who thought otherwise, that teachers were not so far behind the times as might be supposed. Teachers might not say much about such things as the lecturer had described, but the worst thing of all that could happen would be the standardisation of the teacher. If a teacher did not teach according to his own lights and his own methods, he was a bad teacher, and if he was to be limited to standardised apparatus, then the teaching of the country would go down badly in spite of the apparatus.

COLONEL R. E. B. CROMPTON, C.B., R.E., called attention to the extraordinary knowledge of mechanics shown by the lecturer in the very skilful method he had adopted for utilising his splendidly made lenses, the product of the war, so that they could be used by everybody. The system by which he brought his lenses into place with such supreme accuracy was a piece of mechanical adaptation which amounted to a great discovery, and this mechanical skill was evident throughout the whole range of the apparatus. He had been serving with the lecturer for many years on

Standardisation Committees, and had thus seen the development of his mind, and he thought that all Englishmen had reason to be proud of a man who had used his talents so consistently, and made such splendid progress, culminating in what that meeting had been privileged to see. The British had always been the pioneers in standardisation, and Mr. Hoover in America, who was making standardisation the slogan for his election, was only taking what he had been taught by the British, though in America standardisation was being overdone. The aim was to make things fit together, and not to interfere with future design or invention; and in that regard the lecturer had shown a glimpse of a splendid future.

Mr. TAYLOR, in reply, thanked his audience for the very kind way in which they had received his lecture, and for the discussion which had taken place. He had not come to the meeting with any idea of pushing the commercial side of his proposals. His main object was to suggest that the apparatus embodied an idea which ought to be applied to all apparatus to enable it to be made economically and efficiently for teaching. He did not think that the field which the apparatus would find in teaching would be one which would enable the cost of the apparatus to be brought down to a very low figure. He did not think the teaching business itself would absorb sufficient apparatus, but he had thought that it might be made a popular instrument. He had been told that if one wanted to make of it a great popular scientific toy, the one thing to avoid was getting it into the schools!

The CHAIRMAN proposed a hearty vote of thanks to the lecturer, which was carried unanimously, and the meeting then terminated.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

- MONDAY, JUNE 18. Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. General Meeting.
East India Association, at the Caxton Hall, Westminster, S.W. 3.30 p.m. Sir Stanley Reed, "Bombay To-day and To-morrow."
Geographical Society, at the Eolian Hall, New Bond Street, W. 3 p.m. Anniversary General Meeting. Address by President and Presentation of Medals and Awards.
University of London, at King's College, Strand, W.C. 5.30 p.m. Prof. Dr. Edward L. Stevenson, "Early Spanish Discovery in the New World."
5.30 p.m. Dr. H. Wildon Carr, "Some Problems in Metaphysics." (Lecture II.)
- TUESDAY, JUNE 19. Anthropological Institute, 52, Upper Bedford Place, W.C.1. 8.30 p.m. Rev. Neville Jones and Colonel W. E. Hardy, "Stone Implements of South Africa."
Heating and Ventilating Engineers, Institution of, at the Imperial Hydro Hotel, Blackpool. 10 a.m. Mr. T. Roland Wollaston, "Boiler House Efficiency and Economy."
Statistical Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 5.15 p.m.
- WEDNESDAY, JUNE 20. British Empire Producers' Organisation, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 4.30 p.m.
Central Asian Society, at the Royal United Service Institution, Whitehall, S.W. 5 p.m. Mr. Frederic W. Carey, "China: A Survey of the Past Year and Present Position."
Meteorological Society, 49, Cromwell Road, S.W. 5 p.m. (1) Messrs. J. Edmund Clark, I. D. Margary, R. Marshall and C. J. P. Cave, "Report on the Phenological Observations in the British Isles, December, 1926, to November, 1927." (2) Mr. C. K. M.

- Douglas, "On the Relation between Temperature Changes and Wind Structure in the Upper Atmosphere." (*Memoirs*, Vol. 1, No. 7.) (3) Mr. R. M. Poulter, "Simple Formulae for Computing Relative Humidity."
- University of London, at King's College, Strand, W.C. 5.30 p.m. Prof. Dr. Edward L. Stevenson, "Early French and English Explorations in the New World." 5.30 p.m. Dr. H. Wildon Carr, "Some Problems in Metaphysics." (Lecture III.)
- THURSDAY, JUNE 21. British Science Guild, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 5 p.m.
Chemical Society, at Burlington House, W. 5.30 p.m. (1) Messrs. H. M. Dawson and W. Lowson, "Acid and Salt effects in Catalysed Reactions. Part XV. The Catalytic Activity of Hydrochloric Acid in the Hydrolysis of Ethyl Acetate." (2) Messrs. A. A. Goldberg and R. P. Linstead, "The Chemistry of the three Carbon System. Part XVIII. Quantitative Investigations on the $\alpha\beta\text{-}\beta\gamma$ Change in Unsaturated Acids: Observations on the reduction of Sorbic Acid and a new Synthesis of Pyroteterebic Acid." (3) Messrs. G. M. Bennett and W. G. Philip, "The Influence of Structure on the Solubilities of Ethers. Part I. Aliphatic Ethers." (4) Messrs. G. M. Bennett and W. G. Philip, "The Influence of Structure on the Solubilities of Ethers. Part II. Some Cyclic Ethers." (5) Messrs. R. G. W. Norrish and J. G. A. Griffiths, "The Photochemical Decomposition of Glyoxal Vapour."
Royal Society, Burlington House, W. 4.30 p.m.
- FRIDAY, JUNE 22. British Broadcasting Corporation and British Institute of Adult Education, at the Friends' Meeting House, Euston Road, N.W. 8 p.m. Conference to discuss Report of Committee of Enquiry into Broadcasting and Adult Education.
Physical Society, at the Imperial College of Science and Technology, South Kensington, S.W. 5 p.m.
University of London, at King's College, Strand, W.C. 5.15 p.m. Mr. Edward Bensly, "the Satires of Joseph Hall." (Lecture II.)

JOURNAL OF THE ROYAL SOCIETY OF ARTS.

No. 3,944.

VOL. LXXVI.

FRIDAY, JUNE 22nd, 1928.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. 2.

FINANCIAL STATEMENT FOR 1927.

The following statement is published in this week's *Journal* in accordance with Sec. 25 of the Society's Bye-laws:—

INCOME AND EXPENDITURE ACCOUNT.

January 1st to December 31st, 1927.

Dr.	£	s.	d.	£	s.	d.	Cr.	£	s.	d.	£	s.	d.
To <i>Journal</i> , including Printing, Publishing and Advertisements	3,654	17	10				By Subscriptions	6,090	3	0			
„ Library and Bookbinding ..	72	4	10				„ Life Compositions	715	15	0			
„ Medals:—							„ Interest and Dividends on Society's Investments ..	365	0	11			
Albert	21	7	0				„ Ground Rents	377	14	0			
Society's	31	7	3				„ Interest, Dividends, and Ground Rents from Trust Funds for General Purposes	496	5	11			
				52	14	3	Do. from Building and Endowment Funds	22	7	5			
„ Cantor Lectures	223	7	6					1,261	8	3			
				4,003	4	5	„ Sales, etc.:—						
„ Expenses of Examinations ..				13,207	11	8	<i>Journal</i>	290	15	2			
„ House:—							Do. Advertisements	750	0	0			
Rates and Taxes ..:.....	375	2	5				Cantor Lectures	10	13	4			
Insurance, Gas, Coal, Expenses and Charges incidental to Meetings.....	816	17	8					1,051	8	6			
Repairs	402	6	11				„ Examination Fees and Advertisements in and Sale of Examination Papers	14,433	8	11			
				1,594	7	0	„ Charges for Expenses for the use of Meeting Room	323	18	6			
„ Office Expenses:—							„ Rent of Cellars	75	0	0			
Salaries, Wages, and Pensions	4,428	18	4				„ Legacies	100	0	0			
Stationery and Office Printing	651	19	1				„ Balance, being Excess of Expenditure over Income transferred to Capital Account (see Balance Sheet).....	570	5	8			
Postages, Parcels, and Messengers' Fares	264	3	11										
				5,345	1	4							
„ Committees:—													
General Expenses				42	15	6							
„ Industrial Art Committees ..				376	0	3							
„ Interest on Bank Overdraft				52	7	8							
				£24,621	7	10					£24,621	7	10

TRUST INCOME AND EXPENDITURE ACCOUNTS.

Dr.		Cr.		Trust Accumulations, Dec. 31st, 1927:	
	£ s. d.		£ s. d.		£ s. d.
Balance forward	1097 9 2	JOHN STOCK TRUST—			
		By Balance, January 1st, 1927	46 7 1		
		„ Interest on Investments	3 10 2	49 17 3	
		NORTH LONDON EXHIBITION TRUST.—			
		„ Balance, January 1st, 1927	64 0 2		
		„ Interest on Investments	6 14 10	70 15 0	
		DR. ALDRED'S TRUST—			
		„ Balance, January 1st, 1927	65 7 3		
		„ Interest on Investments	7 14 5	73 1 8	
		THOMAS HOWARD'S TRUST—			
		„ Balance, January 1st, 1927	87 18 0		
		„ Interest on Investments	19 19 8		
			107 17 8		
		Less cost of Lectures	30 0 0	77 17 8	
		MULREADY TRUST—			
		„ Balance, January 1st, 1927	49 8 9		
		„ Interest on Investments	6 6 8		
			55 15 5		
		Less Prizes in Industrial Design Competition	20 0 0	35 15 5	
		DR. SWINEY'S TRUST—			
		„ Balance, January 1st, 1927	120 0 0		
		„ Ground Rents (Income from) ..	180 0 0		
			300 0 0		
		Less Transfer to Society's Income and Expenditure a/c ..	140 0 0	160 0 0	
		FRANCIS COBB TRUST—			
		„ Balance, January 1st, 1927	45 1 3		
		„ Interest on Investments	8 18 10	54 0 1	
		LE NEVE FOSTER PRIZE TRUST—			
		„ Balance, January 1st, 1927	18 3 4		
		„ Interest on Investments	6 2 0	2 5 4	
		FOTHERGILL TRUST—			
		„ Balance, January 1st, 1927	17 1 6		
		„ Interest on Investments	13 12 5	30 13 11	
		BENJAMIN SHAW TRUST—			
		„ Balance, January 1st, 1927	22 17 2		
		„ Interest on Investments	4 13 6	27 10 8	
		CANTOR TRUST—			
		„ Interest on Investments	137 3 3		
		„ Ground Rents (Income from) ..	141 0 0		
			278 3 3		
		Less Transfer to Society's Income and Expenditure a/c ..	278 3 3	- - -	
		DAVIS TRUST—			
		„ Interest on Investments	78 2 8		
		Less Transfer to Society's Income & Expenditure Account ..	78 2 8	- - -	
		SIR GEORGE BIRDWOOD MEMORIAL TRUST—			
		„ Interest on Investments	36 15 0		
		Less cost of Sir D. Ross' Lecture (including Printing) ..	36 15 0	- - -	
		RUSSIAN EMBASSY PRIZE TRUST—			
		„ Balance, January 1st, 1927	25 0 0		
		„ Interest on Investments	5 0 0		
			30 0 0		
		Less Prize awarded	5 0 0	25 0 0	
		Carried forward		628 17 0	

SCHEDULE OF THE SOCIETY'S INVESTMENTS.

(as valued December, 1922).

Ground-rents (amount invested)	£10,496	2	9
£217 0 0 Great Indian Peninsula Railway 4 per Cent. Guaranteed Debenture Stock	157	0	0
£500 0 0 New South Wales 4 per Cent. Stock	445	0	0
£500 0 0 Canada 3½ per Cent. Stock	430	0	0
£100 0 0 Queensland 4 per Cent. Stock	97	0	0
£530 10 1 New South Wales 5 per Cent. Stock	514	11	0
£500 0 0 Natal 4 per Cent. Stock	445	0	0
£321 15 9 Metropolitan Water Board "B" Stock	209	3	0
£8 0 0 New River Company Shares	6	0	0
£3,408 14 6 India 3½ per Cent. Stock	2,131	11	8
£500 0 0 South Australia 4 per Cent. Stock	500	0	0
£2,000 0 0 War Loan 5 per Cent..	2,000	0	0
	£17,481	8	5

TRUST FUNDS INVESTMENTS SCHEDULE.

Alfred Davies Bequest	£1,953	0	0	Great Indian Peninsula Railway 4 per Cent. Guaranteed Debenture Stock ..	£1,800	0	0
Dr. Swiney's Bequest	4,477	10	0	Ground-rents (amount expended).....	4,477	10	0
Dr. Cantor's Bequest	2,695	11	3	Do. do. do.	2,695	11	3
Mulready Trust	111	0	9	5 per cent. War Loan, ...	109	10	1
Howard Trust	571	0	0	Metropolitan Railway 3½ per Cent. Stock	510	9	5
Owen Jones Trust	522	3	2	India 3 per cent. Stock	423	0	0
Dr. Cantor's Bequest	3,273	16	6	Do. do.			
	648	19	7	Bombay & Baroda Railway Guaranteed 3 per Cent. Stock	2,573	10	0
J. Murray and others, Building Fund ..	20	16	4	India 3½ per Cent. Stock	20	10	0
	38	11	0	5 per Cent. War Loan	54	18	0
Francis Cobb Trust	255	14	1	New South Wales 3½ per Cent. Stock 1930-50	250	0	0
Le Neve Foster Trust	140	3	1	3½ per Cent. Conversion Loan	100	0	0
	42	2	1	5 do. War Loan	40	0	0
John Stock Trust	70	4	0	5 do. do.	100	0	0
Shaw Trust	93	12	0	5 do. do.	129	6	8
North London Exhibition Trust	134	17	0	5 do. do.	184	15	0
Fothergill Trust	272	7	6	5 do. do.	374	0	0
Aldred Trust	154	8	0	5 do. do.	210	17	6
Endowment Fund	394	7	0	5 do. do.	525	2	3
"Trueman Wood" Lecture Endowment Fund	929	15	8	3½ do. Conversion Loan	654	18	0
Sir George Birdwood Memorial Fund ..	734	19	9	5 per Cent. War Loan	674	0	0
Russian Embassy Prize	100	0	0	5 do. do.	91	9	3
Mann Trust	1,028	9	2	5 do. do.	900	0	0
Thomas Gray Memorial Trust	6,498	7	9	3½ do. do. Conversion Loan	5000	0	0
					£21,899	7	5

TRUST INCOME AND EXPENDITURE ACCOUNTS—continued.

Brought forward £ s. d.
1097 9 2

				£	s.	d.
Brought forward				628	17	0
DR. MANN TRUST—						
„	Balance, January 1st, 1927	91	6	7		
„	Interest on Investments	51	8	6		
		142	15	1		
	Less Paid for Lectures	57	5	0		
					85	10 1
OWEN JONES MEMORIAL TRUST—						
To	Interest on Investments	15	13	4		
	Less Prizes awarded	15	13	4		
					-	- -
THOMAS GRAY TRUST—						
„	Balance, January 1st, 1927	336	3	3		
„	Interest on Investments	227	8	10		
		563	12	1		
	Less Paid for Prizes and Essay	180	10	0		
					383	2 1
TRUMAN WOOD LECTURE TRUST—						
„	Balance due to the Society	32	14	8		
„	Transfer to <i>Journal</i> Account	32	14	8		
					-	- -
					£1097	9 2

£1097 9 2

1928—Jan. 1. By Balance brought forward £1097 9 2

BALANCE SHEET, December 31st, 1927.

Dr.

	£	s.	d.	£	s.	d.
To Capital Account—						
As on January 1st, 1927	76,267	12	2			
Donations re Building Fund	31	5	1			
	76,298	17	3			
Less Income and Expenditure Account Balance ..	570	5	8			
				75,728	11	7
„ Sundry Creditors				885	19	1
„ Bank Overdraft				4,019	5	8
„ Industrial Art Fund (Donations received and not yet expended) ..				403	10	0
„ Preservation of Ancient Cottages Fund (Donations received and not yet expended) ..				3992	3	1
„ Donation received and not yet expended for re-fronting the Strand front of the Society's premises ..				500	0	0
				85,529	9	5
„ Trust Funds—						
Capital Account	21,899	7	5			
Accumulations under Trust Income and Expenditure Account	1,097	9	2			
				22,996	16	7
				£108,528	6	0

Cr.

	£	s.	d.	£	s.	d.
By Freehold Premises						
18 and 19 John Street, as on December 31st, 1923	50,392	16	7			
„ Books, Pictures etc.	10,000	0	0			
„ Investments (see schedule)	17,481	8	5			
„ Subscriptions outstanding	2,201	15	0			
„ Sundry Debtors and Ground Rents outstanding	1,005	18	7			
„ Paid on Account of 1928 Examinations	2,400	0	0			
				83,481	18	7
„ Trust Funds—						
Investments	21,899	7	5			
Ground Rents, etc.	90	0	0			
				21,989	7	5
„ Investment on account of Preservation of Ancient Cottages						
„ Fund—						
£3541 18 3 4% Consolidated Stock	3,000	0	0			
£55 Hampstead						
Garden Suburb						
Debenture Stock	55	0	0			
				3,055	0	0
				£108,528	6	0

We have audited the above Accounts and Balance Sheet for 1927 with the books, accounts and vouchers relating thereto, and certify them as being in accordance therewith. We have verified the Bank Balances and investments.

KNOX, CROPPER & Co.,

Chartered Accountants

Spencer House, South Place, E.C. 2.
13th JUNE, 1928.

NOTICES.

ANNUAL GENERAL MEETING.

The Council hereby give notice that the One-hundred-and-seventy-fourth Annual General Meeting, for the purpose of receiving the Council's Report and the Financial Statement for 1927, and for the election of Officers, will be held, in accordance with the Bye-laws, on Wednesday, June 27th, at 4 p.m.

(By Order of the Council),

GEORGE KENNETH MENZIES,

Secretary.

COUNCIL.

A meeting of the Council was held on Monday, June 11th. Present :— Sir Philip Magnus, Bt., in the Chair ; Lord Askwith, K.C.B., K.C., D.C.L. ; Sir Charles Stuart Bayley, G.C.I.E., K.C.S.I. ; Sir Alexander Gibb, G.B.E., C.B. ; Sir Robert Abbott Hadfield, Bt., D.Sc., F.R.S. ; Col. Sir Arthur Holbrook, K.B.E., M.P. ; Sir Humphrey Leggett, R.E., D.S.O. ; Sir Reginald A. Mant, K.C.I.E., C.S.I. ; Col. The Master of Sempill ; Mr. Alan A. Campbell Swinton, F.R.S. ; Mr. Carmichael Thomas, and Lt.-Col. Sir A. T. Wilson, K.C.I.E., C.S.I., C.M.G., D.S.O., with Mr. G. K. Menzies, M.A. (Secretary) and Mr. W. Perry, B.A. (Assistant-Secretary).

The terms of the award of the Society's Albert Medal for 1928 were settled [see page 810, below].

The draft report of the Council for the current session was considered and approved.

The offer of a number of prizes under the Thomas Gray Memorial Trust having for their object the improvement of the Science and Practice of Navigation was approved. [Particulars of the prizes will be published in a subsequent number of the *Journal*.]

The thanks of the Council were accorded to Mr. James H. Hyde for a further donation of £500 to the Fund for the Preservation of Ancient Cottages. Mr. Hyde had already contributed £1,025 to the Fund.

The number of entries for the Competition of Industrial Designs was reported. This year there are 1,083 candidates and 3,145 designs, as compared with 745 candidates and 2,224 designs in 1927.

The arrangements for Session 1928-29 were considered.

The following candidates were duly elected Fellows of the Society :—

Barrett, Thomas Francis, Weybridge, Surrey.

Brockbank, Clarence J., Philadelphia, Pa., U.S.A.

Coulter, Vincil Carey, M.A., Laramie, Wyoming, U.S.A.

Foxall, Arthur J., Los Angeles, California, U.S.A.

Gosney, George Frederick, London.

Hertz, His Honour Frank R., Charlottetown, P.E.I., Canada.
 Henstock, Herbert, M.Sc., Ph.D., F.I.C., Shrewsbury.
 Kapur, Dewan Gokulchand, Benares City, India.
 Radcliffe, Bramley Norman, Stalybridge, Cheshire.
 Roberts, Robert William, Aberystwyth.
 Sennett, Colonel C. T., La Turbie, France.
 Turvey, Henry C. W., Sheffield.

THE SOCIETY'S ALBERT MEDAL.

The Albert Medal of the Society for the current year has been awarded by the Council, with the approval of the President, H.R.H. the Duke of Connaught, to Sir Ernest Rutherford, O.M., LL.D., D.Sc., F.R.S., Cavendish Professor of Experimental Physics, University of Cambridge, "for his pioneer researches into the structure of matter."

The Medal was founded in 1863, as a memorial to Prince Albert, for eighteen years President of the Society, and is awarded each year "for distinguished merit in promoting Arts, Manufactures and Commerce."

BINDING COVERS FOR JOURNALS.

For the convenience of Fellows and others wishing to bind their annual volumes of the *Journal*, cloth covers can be supplied, post free, for 2s. each, on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.

DOMINIONS AND COLONIES SECTION.

TUESDAY, MAY 22ND, 1928.

LT.-COL. THE RIGHT HON. SIR MATTHEW NATHAN, P.C., G.C.M.G., LL.D.,
in the Chair.

THE CHAIRMAN, in introducing the lecturer, said that Sir Cecil Armitage had served for a third of a century—and a good deal more than half his lifetime—in West Africa. Sir Cecil had first gone to the Gold Coast and the Bight of Benin at a time when "few came out though many went in." Then he had served in Ashanti in two expeditions. It was there that he had had the pleasure of making Sir Cecil's acquaintance. Sir Cecil had then been Commissioner of the Southern Province of Ashanti. He remembered talking about Sir Cecil with the then Chief Commissioner, Sir Donald Stewart, and being told "Captain Armitage is a thoroughly reliable man." He had found him so when Sir Cecil himself became Chief Commissioner in Ashanti a year or two later. From there Sir Cecil went to the Northern Territories of the Gold Coast as Chief Commissioner—by no means an easy post, with a great variety of tribes in different degrees of savagery—and proved himself the same reliable officer as he had been in Ashanti. Thence he went to the Gambia, of which colony he was about to tell the audience.

The following paper was read :—

THE GAMBIA COLONY AND PROTECTORATE.

By CAPTAIN SIR CECIL ARMITAGE, K.B.E., C.M.G., D.S.O.,

Late Governor and Commander-in-Chief of the Gambia Colony and Protectorate.

Among the many thousands of people who visited the British Empire Exhibition at Wembley, but few could have failed to notice the large electric sign that appeared on the walls of the Nigerian Pavilion in the " Walled City " of the West African Section of that Exhibition. A figure of Brobdingnagian proportions represented the inhabitants and area of Nigeria : smaller and dwindling figures of those of the Gold Coast and Sierra Leone, while a fourth, of Lilliputian size, stood for the Gambia Colony and Protectorate. I wonder if any of those sight-seers realised the fact that at one time the British sphere of influence in that part of West Africa comprised the whole valley of the Gambia River which, had it been retained, would have swelled the tiny figure that to-day represents the Gambia to proportions comparable with those of Nigeria.

It may be that Phœnician voyagers were the first to set eyes on the shores of the Gambia, but this is a matter for conjecture. Less so is that of the voyage of Hanno, the Carthagian, who conducted a fleet of sixty vessels down the West Coast of Africa in the year 450 B.C. and must have entered the Estuary of the Gambia River and sailed up it some considerable distance, for Dr. Leyden's translation of the *Periplus of Hanno*, describes accurately the mouth of the River, and what is to be seen to-day : the dense mangrove swamps that lined its banks : the fires that blazed behind them at night—fires that burn to this day as the long grass is destroyed during the dry season in order to clear fresh land for cultivation during the rains. Then, too, the adventurers made the acquaintance of the Guinea Baboons. They called them " *Gorillæ* " and described them as of " human form, but shagged and covered with hair." They succeeded in catching three, which did not survive, but it is recorded that their skins were carried to Carthage and there exhibited.

About the middle of the 15th Century a Venetian, Alvico Cada Mosto, conducted an expedition that was fitted out by Prince Henry of Portugal " the Navigator "—to the Gambia, and from him we get the first descriptive account of the country. Thence onward the Portuguese kept the trade of the " Secret River " in their hands, until, in the reign of Queen Elizabeth, English Merchants obtained a patent in the year 1588 to trade for ten years in the Senegal and Gambia Rivers. I will spare you a dreary and lengthy account of all the vicissitudes through which the country passed at the hands of the roving Dutch, English, French and Portuguese adventurers, all of whom competed for the exclusive control of " the River of secret trade and riches."

Portuguese dominance gradually waned and, early in the 17th Century, English and French were left in undisputed rivalry. The former established

themselves in the Gambia : the latter in Senegal, but for the next two hundred years both contended with varying fortunes, for supremacy over the whole of that vast area and the trade of its hinterland. The little Island of " St. James," which possesses the proud distinction of being the first British Possession on the West Coast of Africa, became a bone of contention. It rises from the centre of the river bed some sixteen miles east of Bathurst and the guns of the Fort, said to have been built by one George Thompson in mid-seventeenth century, commanded both banks of the river and prevented its ascent by foreign vessels. On the right bank and within two miles of James Island, the French made their first settlement, Albreda, after they had temporarily captured the fort in 1698. In 1760 we were in possession of Senegal, but by the Treaty of Versailles, it, with the Island of Goree, was handed over to the French.

In the 18th Century the commerce of the Gambia was controlled by the Royal African Company, which prospered exceedingly from its dealings in slaves, gold, ivory and beeswax. This prosperity was maintained until the Act of 1807, abolishing the slave trade, ruined the Company, which, in spite of an annual subsidy of £23,000, failed to make any profits, and finally its assets were taken over by the Crown.

In 1816 it was decided not to rebuild Fort St. James, for the little Island was gradually decreasing in size. Frances Moore, a factor and writer to the Royal African Company from 1730 to 1735 thus describes it :—

" James Island lies almost in the middle of the River Gambia, which is here at least seven miles wide. It belongs to the Royal African Company of England, who pay a small annual tribute to the King of Barraah for the same. It lies three miles from the nearest shore and about ten leagues from the river's mouth.

At low water it is about three-quarters of a mile in circumference, upon which there is a square fort of stone, regularly built with four bastions : upon each are seven cannon well mounted, which command the river ; under the walls of the Fort, facing towards the sea, are two round batteries ; on each of these are four large cannon well mounted, and between those are nine small guns mounted for salutes."

It was thus equipped :—

" The Island walled all round, outworks, small arms with stores, etc., formerly mounted with ninety small guns, now with thirty-eight great guns, with several warehouses, with rooms for the Governor, factors, writers, officers, artificers, soldiers and castle-slaves ; magazine and storehouses with a negro-house for two hundred negroes."

When the English Governor of the Island capitulated to the French—Comte de Gennes—in 1692 it had a garrison of from 60 to 70 Europeans. What life must have been, alike for Europeans and Africans, passes comprehension ; mewed-up, as they were ; within such circumscribed limits and surrounded

by the brackish waters of the River. Fresh water had to be brought from the mainland, for no spring existed on the Island, and one of the Comte de Gennes' colleagues has stated that the place lacked a "bomb-proof" water cistern or a similarly protected magazine: which defects brought about the capitulation. Herded together by day under a tropical sun and exposed by night to the chill winds that blew from the East, existence must have been well nigh intolerable.

A new site for the future capital of the Colony was selected on St. Mary's Island, at a point which commanded the Fairway Entrance to the River, and was named "Bathurst" by Sir Charles McCarthy, by whom the town was designed. Sierra Leone was chosen as the seat of Government, with a jurisdiction that included the Gambia, the Gold Coast and all other British Settlements. An Island situated some 150 miles up the River was purchased from the native Chiefs in 1823, and was called after Sir Charles McCarthy, the Governor, who later lost his life in the Gold Coast, in a gallant attempt to arrest the advance of the Ashanti Army into that Colony. It was incorporated with the little Colony, and at one time, Georgetown, the town that sprang up on it, was but second in importance to Bathurst and the depôt for the trade and produce of the upper River, to which ocean-going steamers could ascend. The wharf town of Kuntaur, situated on the right bank of the river about 20 miles down the stream, has now displaced it in importance as a ground-nut depôt for loading up steamers, which are able to moor close along-side its banks. In 1843 the Gambia severed its connection with Sierra Leone and was promoted to the dignity of a separate Colony with a Governor of its own and in 1857 the exchange of Albreda was effected and the Gambia became wholly British. In 1866 it was again merged in "the West African Settlements" and, under a local administrator, was governed from Sierra Leone. In 1888 it finally became a separate Government.

The nineteenth century witnessed our retrograde movement in our African Colonial policy and a marked desire by the Home Government to withdraw from West Africa. On the other hand the activities of France in the direction of expansion increased, as ours became supine, and in 1887 England withdrew her claim to the Watershed of the Gambia while further concessions to France in connection with the Newfoundland Fisheries disputes reduced to its present restricted limits our nearest tropical Colony to England.

To-day the Gambia is but an enclave of French Senegal, into which it extends eastwards for a distance of about 250 miles along the banks of the Gambia River. The total area of the Gambia is about 4000 square miles, of which the Colony claims but sixty-nine. Its boundaries, as fixed by agreement with the French in 1889, follow the windings of the river at a distance of ten kilometres, or six and a quarter miles, from either bank: surely the most impossible and ridiculous demarcation that has ever been undertaken, for—apart from arbitrary severance of Tribal Lands and even the cutting in twain

of established villages, with the result that the inhabitants, once united, find themselves separated under dissimilar administrations—the erosion of, or accretion to, the river banks by the action of the yearly floods cannot have been taken into consideration. Needless to say that the criminal classes take the fullest advantage of these fantastic borders, across which they skip as necessity, that knows no law, demands !

The Gambia is populated by negroes of the Jollof, Mandingo, Sarahuli, Fula and Jola tribes, and are, with the exception of the last named, Mohammedans, in a more or less strict sense of the term. Noted warriors in the past, and engaged in endless internecine warfare, in which loot and the capture of their enemies to sell into slavery to the “ White Man,” or to retain themselves as “ hewers of wood and drawers of water,” were the main objects, they have of late years accepted the advent of a benevolent and peaceful administration.

As agriculturalists and farmers they are an amenable, contented and lovable people, among whom the worst forms of crime are of rare occurrence, while that of the more venial kind is steadily on the decrease.

When you have seen one Gambian village you have seen all, so far as “ architecture ” is concerned. This takes the form of grass and wattle circular shaped hutments with conical grass roofs which are run up together in family groups and are surrounded by enclosures of “ crinting,” or mats of plaited grass, or palm leaves. Little wonder is it that these flimsy hamlets constantly go up in flame during the dry season of the year.

The population of the Colony and Protectorate to-day may be estimated at a little under a quarter of a million. The men affect as attire flowing Mohammedan robes, and the women coloured cotton gowns, or cloths of native woven material, but both sexes discard all superfluous clothing when at work on their farms. The cultivation of the ground-nut is almost universal and constitutes the main industry on which the prosperity of Gambia depends. A peculiar feature of the industry is the influx, during the yearly sowing season, of Senegal natives in large numbers. These are known as “ strange farmers ” who, in return for the work that they perform on their host's farms, in addition to their own, are fed by our natives. They return to their country, after disposing of their crops, with the wherewithal to pay the annual tax levied on them by the French Government. The construction of railways by our neighbours, that will eventually surround the Gambia and deprive it of this labour supply, has already made its influence felt, for the number of “ strange farmers ” visiting the protectorate has fallen steadily from over 24,000 in 1921 to 14,000 in 1926. The establishment of an Agricultural Department in 1924 has, however, counteracted this serious loss of labour, for whereas a crop of but 39,000 tons was recorded in 1924, crops of 59,000 were reported in 1926 and of over 60,000 in 1927, as the result of the stimulus given to the “ home ” farmers by that Department, which did not confine its attention to the ground-nut crop alone, but succeeded in encouraging the natives to produce increased

food supplies which resulted in 1926-27 of a harvesting of cereals—Guinea corn, maize, millet and rice—that was pronounced as being “wonderful” and of a size seldom before seen in the Gambia. Farming in the Protectorate is not unattended by difficulties, for the plantations are frequently devastated by the raids of baboons, monkeys, wart hog, and even of hippotami, while clouds of birds descend on the ripening cereals and keep a small army of children employed in driving them off.

Palm kernels and hides are also exported from the Gambia, but are to-day almost negligible as a source of revenue. The large herds of cattle that were once possessed by the Protectorate natives have been decimated during recent years by epidemics, which appear to originate in Senegal. The principal imports to the Colony are cotton goods, hardware, kola nuts, (which are transported up country for sale throughout North West Africa), provisions, (including flour, rice and sugar) and tobacco.

The education of the rising generation is not neglected, but is at present in the hands of the Missionaries of the three denominations established at Bathurst,—Anglican, Wesleyan and Roman Catholic. Some fifteen hundred children attended their Elementary Schools which are subsidised by the Government. There are also Mohammedan Schools at Bathurst and McCarthy Island. It is a sad fact that the parents exhibit an apathetic attitude towards the education of their children and usually remove them from school when they reach the age at which they become useful members in the household. The Boy Scout and Girl Guide Movements have been established at Bathurst, but here again the attitude of insensibility of the children's parents towards these wonderful aids to the training of the youth of the Country has to be faced.

The climate of the Gambia from about the end of November to the middle of the following June may be described as pleasant and fairly healthy. Practically no rain falls during those months, but heavy night dews keep the vegetation from desiccation. On the other hand the rainy season—June to October—is distinctly unhealthy and up River alternates erratically between extremes of temperature. The annual rainfall as recorded at Bathurst over a period of some thirty years has averaged 45 inches, and that in the Protectorate some ten inches less. On the even distribution of the the rainfall over the period of the planting season the success or failure of the ground-nut and cereal crops very greatly depends.

DISCUSSION.

THE CHAIRMAN said the lecturer had given an able summary of the ancient history and of the modern conditions of the Gambia, and had followed it up by a series of most interesting and artistic pictures. His own small experience of the Gambia belonged to its ancient history. He had passed through there some 45 years ago on his way home from Sierra Leone. He had noted in his diary

then how inferior were those fortifications to which the lecturer had referred ; also that the town of Bathurst was a very clean town ; and he found a reference to the European built houses of stone or bricks, whitewashed interior courtyards, high slate roofs and the cotton trees which the lecturer had depicted in some of his slides. He had noted also that there was a good deal of dissatisfaction among the merchants with regard to the Government. The merchants complained that the Government was interfering in their business, and particularly that it was taking the excess of revenue over expenditure from the Gambia in order to finance ineffectual and inconclusive native expeditions in Sierra Leone. The trade was then said to be declining and the whole revenue of the Colony was some £25,000 and the expenditure about £20,000. The revenue was now about eight times as much. The imports had been about £150,000 and the exports about the same. Now the imports were over four times that amount and the exports were greater than the imports. The Settlement at that time had been confined to what was now called "the Colony." There had been no Protectorate, and the population had been estimated at about 15,000. It was now close on a quarter of a million. There had evidently been a great deal of progress in spite of the prognostications which had obtained 45 years ago, and he expected part of that progress was due to the administration of Sir Cecil Armitage.

(SIR WILLIAM N. M. GEARY, Bt., D.L., here took the Chair, Sir Matthew Nathan having unavoidably to leave, a hearty vote of thanks being accorded to Sir Matthew for having presided.)

DR. W. RUSHTON PARKER, M.D., enquired for what purpose ground nuts were utilised.

SIR CECIL ARMITAGE replied that ground nuts had both an oil and a food value. The margarine industry was greatly dependent on the oil product of the ground nut. There were several varieties of ground nuts. Some were used by confectioners for cakes, sweetmeats and other things, but the Gambian ground nuts were grown mainly for the oil trade. After the oil had been expressed, the residue was used for cattle cake.

CAPTAIN SIR DAVID W. BARKER, R.D., R.N.R., congratulated the lecturer on his very interesting paper on what was a most charming little colony. In 1886 he himself had been sent out to lay the first cable there. In 1922 he had gone out, by order of the Colonial Office, to help to develop the River Department, and he had found an exceedingly business-like lot of people there who were very anxious, under Sir Cecil's helpful administration, to make their beautiful waterway a successful proposition. It was a very curious thing that English politicians had always been very cold towards the Gambia Colony. He fancied that when they had delimited the area they had thought that kilometres were the same as miles. The geographical knowledge possessed by a good many of our politicians was very much lacking. The Gambia was a very fine river, although not a very long one, and it possessed one of the finest harbours on the coast of Africa. That harbour had no bar, and at some time it might be extremely useful to us to have such a place which could accommodate so large a number of vessels. The accommodation of 30ft. of water extended for over four miles in one direction and for one and a half miles in the other. The recently established Agricultural Department of Gambia should quite easily be able to make a wonderful "market garden" of that small colony. The rainfall was not excessive, but it was quite

sufficient to keep the ground more or less in a state suitable for agriculture—which up to the present had not been developed ; there was very much still to be done in that direction. The main thing, however, was the river, because from the river went little creeks in all directions which were the only means of communication between the country and the river, as to make roads and to build bridges to cover those creeks would be an extremely expensive matter. If the river and the means of communication by water were not developed, the ground nut plantations would be tapped by the railways which were being developed over the border. He had, however, no fear of that, if the policy which had been adopted by Sir Cecil was developed, as he believed it was being developed at the present time, so as to make full use of that splendid river. With regard to health, personally he had been a good deal in the tropics, and he could safely say that health in the tropics depended almost entirely upon adapting oneself to the conditions in which one found oneself. For instance, one could enjoy a beefsteak in England, but one could not enjoy a beefsteak in the tropics in the same way. That was a fact which many people lost sight of altogether. He was quite sure that modern researches would make the Colony very much more healthy even than it was at the present time.

DR. W. RUSHTON PARKER asked the lecturer if he was quite satisfied that Hanno the Carthaginian, in 450 B.C. had really made the acquaintance of the Guinea Baboons. Personally, he had always understood that there was some difficulty in ascertaining with certainty what the animal was which Hanno called a gorilla. He understood from what the lecturer had said that Hanno had not captured any of the males, but had captured two or three females, which had died. Would it have been possible for that expedition to have mistaken a Guinea Baboon for a human being— a " wild " man—or could it have been a chimpanzee ?

SIR CECIL ARMITAGE replied that one had only to look at the ancient maps of Africa to realise that anything could be mistaken for anything else. One read on such maps " Here be cannibals ; here be dragons ; here be monsters," and so on. When the Carthagians had seen those uncouth baboons leaping about and gibbering at them from the rocks, no doubt they had naturally assumed that they were some debased form of humanity and had called them " gorillae." He did not know the derivation of the word. The expedition had captured three females. The males had evaded them. Even in those days it seemed that the females were braver in the defence of their young than the males, and that was how the females had been captured.

MR. J. A. BARBOUR-JAMES thought a meeting of the present kind would not be complete if an African did not say one or two words. He himself was a son of Africa, born outside Africa in Guiana. Nearly 25 years ago he had been translated from his home service in Guiana to the West African Service, where he had served the Crown for 15 years, during which time Sir Cecil Armitage had been an official of the Colony. He had had the great pleasure of meeting Sir Cecil Armitage on several occasions, and he could bear the highest testimony to the splendid service which Sir Cecil had rendered to the colony. He desired to bear special testimony to Sir Cecil's efforts in the matter of an educational scheme whereby Africans from Gambia should be sent to England to acquire knowledge and education and then return to their colony and assist their kinsmen. Sir Cecil had referred to the apathetic attitude of the parents in Gambia towards the education of their children. Was it not possible for the Government to take

steps to bring about a compulsory system of education in the colony? Such a system would be the means of training children up into educated men and women to the great advantage of the colony. He was very glad that Sir Cecil had referred to the fact that there had been some ancient civilisation in those parts of Africa, as some thought that the Africans had no past, and therefore must be considered of no importance. Africa's sons and daughters owed a deep debt of gratitude to men like Sir Cecil Armitage, who, from the depths of their experience, gave the peoples of Europe accounts of the developments which had taken place in the African colonies; and he was certain that if the sons and daughters of Africa would only take advantage, and were given opportunities of taking advantage, of the facilities for education and advancement and the fair play which were offered them, they would proceed towards a higher stage of development and civilisation.

SIR WILLIAM GEARY, in moving a hearty vote of thanks to the lecturer for his very interesting address, said the one fault he had to find about the address was that Sir Cecil had not said much about himself in it. He could testify, however, what a good officer Sir Cecil had been. He had gained the Distinguished Service Order during a very perilous period in the siege of Kumasi, when he had been sent out in the quest of the Golden Stool. Neither had Sir Cecil said much about health, but personally he could say that the Gold Coast, and West Africa in general, was still not a bad place for health. He had recently written a book upon Nigeria, in which he had shown that the death rate before 1900 had been 80 per thousand; that during the next ten years it had gone down to 31 per thousand, and that during the following ten years it had gone down to 13 per thousand. In Sir Cecil Armitage, the colony of Gambia had enjoyed a very diligent Governor—a Governor who had been in residence there longer than any previous Governor. Now that Sir Cecil had retired, it was to be hoped that he would devote his energies to his home country, and he hoped Sir Cecil would enjoy a long life in which to enjoy his retirement.

The vote of thanks was then put and carried unanimously.

SIR CECIL ARMITAGE briefly acknowledged the vote, and the meeting then terminated.

CORRESPONDENCE.

CO-PARTNERSHIP v. "MONEY-LENDERS."

Mr. George L. Boag, in your issue 1st June, deals with the above subject and I venture to criticize some of his statements. He definitely states that Capital and Labour are equally risking. There is, of course, no *equality* of the risk and quite rightly so. It is not right that Labour should be expected to risk on my—or any other business man's—judgment and enterprise. I risk my capital and my home, in addition to my job, but my workers leave their homes untouched; it is only their job they risk in my enterprise.

Mr. Boag talks of the "moneylender" doing terrible things. I have had the advantage of borrowing hundreds and even thousands of pounds from Banks, etc., but I have never come across this "intervening" and "game of cut-throat," and

"holding all the cards," which he talks about. I have simply gone to the Bank with a business proposition which they or I can refuse or accept. I look upon the Bank as my best friend.

Mr. Boag speaks of the increasing practice of "commencing a business regardless of ethics, with a proportion of loan capital in addition to the share capital." A man starts a business in debt, because some people with their eyes open have showed sufficient faith in him to lend him money. I am afraid Mr. Boag sees troubles which do not exist. He appears to fear that the City of London is so highly organised, politically and otherwise, that the trade unions will be left out in the cold. I know a good many Trade Unionists, and I can assure Mr. Boag that they are quite able to look after themselves.

Fortunately, with the introduction of Whitleyism into so many industries, both Capital and Labour are learning more and more to appreciate the good points of the other man.

H. V. ROE.

THE MODERN TYPEWRITER.

Would you allow me to draw the attention of your readers to the important remark of Mr. E. Pitman (page 737, J.R.S.A.)? The practical difficulty of which he speaks, viz., "the spelling of English words," no longer exists.

I have still in use a typewriter made by the Smith Premier Co., which should have been exhibited to illustrate the lecture which I gave at University College, Nottingham, a short time ago. It "records spoken sounds in the form of the very erratic English spelling," by the addition merely of the eight geometrical elements, *i.e.*, the perpendicular and horizontal lines, the four segments of the circle, the dot, and the angle.

These indicate, just as in ordinary mechanical drawing, the movements of the vocal organs which produce and differentiate the sixteen vowel sounds in English, and correct the ordinary print. Very few consonant signs suffice, in conjunction with the vowel signs, to render the print *absolutely phonetic*. These signs can be added to any kind of typewriter for a few shillings.

This system of notation, which is patented, is known as "Orthotype." Nothing but the notorious apathy of the Englishman with regard to his language has hitherto prevented its universal adoption.

A. DEANE BUTCHER.

NOTES ON BOOKS.

TIN MINING. By C. G. Moor, M.A. (Cantab.) London: Sir Isaac Pitman and Sons, Ltd. 8s. 6d. net.

This book of 170 pages purports to be a guide for prospectors and all interested in the mining of tin. It is a book that would certainly be useful to students and may possibly be acceptable to experts, as a reminder of the various branches of the industry and as putting, in short form, points of which it is desirable for them to take note. For those who wish to consider the history of tin, the last chapter containing historical mentions of tin from 3500 B.C. down to the present day, and the appendix indicating the characters of minerals sometimes mistaken for cassiterite, can be read first, but the student desiring to attack physical characters,

methods of prospecting, milling and dressing and, later, a dissertation on alluvial mines, can commence with the first chapter. The ordinary reader will be interested in the description of a lode and particularly in the uses of tin described on page 110, a subject upon which there is much popular ignorance.

The writer clearly indicates how tin mining has been changed during the last two centuries, which the celebration of the bicentenary of the introduction of tin rolling in Great Britain recently called to mind. New processes, particularly in dredging and in extracting a larger percentage of marketable cassiterite, have enabled low grade ores to come upon the market which formerly were not worth treating. Even now the use of low grade ore must depend upon the price at which it can be sold and the cost of treatment. Although the world's production is steadily increasing, yet the known sources of supply are being used up very quickly and the demand for tin increases year by year. As the writer correctly remarks: "The supply of alluvial tin is not unlimited and there is every reason to believe that the demand for tin and its uses will extend rapidly every year. We must expect, therefore, something in the nature of a world shortage."

The author concludes with a prophecy interesting to this country, when he says in regard to Cornwall: "There are many areas where it is known that there is payable ore and, if it is possible to gain the support of investors, there is nothing to prevent the industry from becoming greater and more prosperous than it has ever been in the past."

The test is now being made in Cornwall by powerful associations and it may be hoped that the results of their efforts will dissipate the "impression among many people that the West of England mines are exhausted."

MODERN FURNITURE VENEERING. By E. W. Hobbs. London: Crosby Lockwood and Son. 5s. net.

The word veneer has not altogether a good name. Used technically, it should be respectable, but is not always. Mr Shapland, in his Cantor Lecture before the Royal Society of Arts, said that "veneering is widely supposed to be a questionable practice, the covering of an inferior material by some better material."

This is, of course, a misconception of the art or practice of veneering, examples of which are in existence dating from Egyptian times. Modern cabinet makers are satisfied that veneers can *endure*; on the other hand, the æsthetic justification of thus overlaying furniture is quite clear. The kind of effects which depend on interesting disturbances of the grain of a wood are not to be obtained from the wood when cut so as to be strongest for the framework of furniture. Thus "most of Chippendale's cabinets, sideboards, clock-cases, and so on were built of plain Spanish mahogany and veneered on the flat surfaces with curl or other figured Spanish mahogany . . ."

Big flat surfaces are characteristic of much modern furniture. Taste to-day is in favour of subtle simplicity and hostile to the rococo. Heavily applied ornamentation and even comparatively chaste mouldings are abandoned, and instead we have decorative veneers in every sort of wood. The illustrations at the end of Mr. Hobbs' book show some typical English and Continental furniture of the day, with its straight lines and its veneers of walnut and rosewood, acacia and laurelwood.

The greater part of Mr. Hobbs' work is in the nature of a practical manual. He describes veneering in practice, speaks of the texture and grain of the various woods, and gives minute particulars of all sorts that are likely to be of use to the cabinet-maker. His list of available woods is most interesting.

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.(2.)

NOTICE.

INDIAN SECTION.

A meeting of the Indian Section Committee was held on Thursday, June 21st, to consider the arrangements for meetings of the Section during the forthcoming session. The following were present:—Sir Reginald Mant, K.C.I.E., C.S.I., in the Chair; Sir Philip Magnus, Bt., Chairman of the Council; Sir Charles Armstrong; Sir Charles S. Bayley, G.C.I.E., K.C.S.I.; Sir George Barnes, K.C.B., K.C.S.I.; Mr. W. Coldstream, I.C.S. (retd.); Sir Edward A. Gait, K.C.S.I., C.I.E.; Col. Sir A. Henry MacMahon, G.C.M.G., G.C.V.O., K.C.I.E., C.S.I.; Mr. N. C. Sen, O.B.E.; Brig.-Gen. Sir Percy M. Sykes, K.C.I.E., C.B., C.M.G.; Mr. Carmichael Thomas; and Sir Arnold T. Wilson, K.C.I.E., C.S.I., C.M.G., D.S.O., with Mr. G. K. Menzies, Secretary of the Society, and Mr. W. Perry, Secretary of the Section.

PROCEEDINGS OF THE SOCIETY.

TWENTY-FIRST ORDINARY MEETING.

WEDNESDAY, MAY 9TH, 1928.

PROFESSOR R. STENHOUSE WILLIAMS, M.B., C.M., B.Sc., D.P.H., Research Professor in Dairy Bacteriology, University College, Reading, in the Chair.

THE CHAIRMAN said he did not think there was anything that a chairman could do which was more cruel than to stand between the lecturer and his audience. All he would say, therefore, in opening that meeting was that Captain Lane was one of those members of the dairy industry who were endeavouring to do their work in the best possible way. With that brief introduction he would ask Captain Lane to read his paper.

The following paper was then read :—

THE STERILIZATION OF MILK.

By R. W. LANE.

Although different methods of sterilization are adopted in various countries, both as regards temperature and process, I propose, owing to the time at my disposal, to deal in this paper chiefly with the method of sterilization adopted in Great Britain. It is therefore, essential to explain that, when the term "Sterilized Milk" is used, it refers to milk that has been heated to 100 degrees C. and retained at that temperature for twenty-five minutes, in order to correct the assumption made, even by people in well-informed circles, that milk subjected to sterilization is boiled for a prolonged period at an excessive temperature until every conceivable type of bacteria, including the spore, is destroyed, and the vitamin irreparably injured. I will endeavour to demonstrate that not only is this not the case in properly-regulated sterilised milk dairies in this country, that is, where a pride is taken in the product and processing, and reputation is placed before all other considerations, but that milk can be raised to 100 degrees C. and retained at that temperature for twenty-five minutes without any injurious effect upon its nutritive value; and that, when this is done, perfectly satisfactory results can be obtained in regard to necessary commercial requirements, while public health and hygiene are greatly assisted.

Confusion often arises between the processes of sterilization and Pasteurization. It cannot be too definitely stated, or too widely known, that beyond a certain unfortunate similarity in name, the comparison ends. For not only are the processes entirely different, but the objects for which they are used are different also. By Pasteurization we mean milk that has been raised to 63 degrees C. (or 145 degrees F.) and retained at that temperature for thirty minutes, and it is claimed by those adopting this method that this is sufficient to destroy all pathogenic organisms. It will be seen at once that the differences in temperature are very great, but I will firstly confine my remarks to the purely commercial aspect of sterilization.

Firstly, the great advantage of sterilization is that it enables exportation to any country where a demand for fresh liquid milk for children exists, as, for instance, in the Tropics. If the process I am about to describe is properly carried out, there is no reason why the milk should not remain sweet in the hottest climates for very considerable periods, provided, of course, reasonable care is taken.

From my own experience I know that it has been taken from London for use on a voyage to Bombay, and from thence by rail across India to Calcutta, where the remainder of the consignment was used, and no bottle was found to have gone sour. I think you will all agree this was a very severe test. This is not only a singular instance; it has been consigned in this way frequently.

It has also been sent with the same result to Malta and South Africa, and is invaluable on board ship, being, in fact, in regular use in the ships of the City Line, Union Castle Co., and several others. For these reasons alone it is deserving of consideration and support from British Authorities.

I have frequently tried the experiment of keeping sterilized milk in England for very long periods, and have invariably found it perfectly sweet on being opened, even after two years have elapsed, and this without the assistance of any cold storage, and simply at ordinary room temperature.

In regard to its uses in this country, the fact that it is only necessary to deliver it once a week to retail customers renders it essentially of the greatest convenience, especially in the poorer districts, where no servants are kept, and both husband and wife go out to work. Also, by this method a constant supply of pure, wholesome milk is at all times available in the house during the night or day, a very important matter where young children are concerned. This system of once-a-week delivery effects economy in distribution and largely covers the increased cost of processing. So much so, in fact, that this class of milk was retailed previous to 1914 at the same price as raw milk in an open can, and is to-day only one penny per quart above the ordinary price of raw milk, owing to the increased price of bottles, crates, and wages, etc., since that date. Thus it will be apparent that sterilised milk is not a rich man's luxury, but caters for the million.

The most important feature in conducting a sterilized milk business is to see that only milk with no more than twenty degrees of acidity is used, for no amount of sterilization in the world can make sour milk sweet. The real danger lies not so much in milk that arrives actually sour, for that can be easily detected and returned as unfit, but in what one may term "border line" milk, that is to say, milk which, though excessive in acidity, is not sufficiently tainted to prohibit use in the ordinary milk trade, where consumption is rapid. It is extremely difficult to detect this "border line" milk, for it is not sufficiently sour to return to the farmer in the ordinary way, and although it will pass through the process quite well, and even last after delivery, it will be found that about the second or third day after the milk has been left at room temperature in the consumer's house, souring, using the term in its most general sense, will occur. This is due to the presence of spore-forming and heat-resisting bacilli whose growth has been merely retarded during commercial sterilization.

Recent investigations have shown that there are various types of bacteria prevalent in milk which are capable of causing serious trouble. Amongst such are bacilli of the type of *B. Subtilis*, which are most prevalent in hay and straw, and are also to be found in dust, and which will survive a temperature of 100 degrees C., even when retarded at the same for a prolonged period. So that, if it is not desired to heat the milk above this temperature, it is necessary to keep this type of bacteria out of it. It will therefore be seen that the question

of clean milking becomes of the first importance, for the lower the bacteriological content of the milk in the first instance, the easier it becomes to render it sterile, provided, of course, that the particular types above mentioned are eliminated. It therefore becomes of the first importance for the dairyman supplying sterilized milk to safeguard himself by only purchasing his supplies from the cleanest possible source, and to ensure doing so it will be well worth his while, if necessary, to pay more than market price for the milk he requires. If a proper supervision is exercised he will be more than compensated by not having a large number of changes during the summertime, and it is in this respect that the scientist can be of inestimable value to the commercial dairyman, and an efficiently-equipped laboratory under the direction of a skilled bacteriologist will be found to be not only absolutely essential, but a profitable department. All milk coming in to the dairy should be examined, not only for acidity, but also for an estimation of its bacteriological content, butter fat, and general cleanliness, and a report sent once a week to each individual sender. My own experience goes to prove that the farmers, far from resenting this as an unwarranted interference, much appreciate it, and take the keenest interest in their reports from week to week. It enables them to check the work of their milkers as to cleanliness and efficient cooling, and enables them to take an interest in their work, incidentally assisting them very greatly if they are competitors in their local Clean Milk Competition, which they most certainly should be encouraged to support. It is also necessary for the bacteriologist doing this work to make periodical tours of inspection of the farms under his or her control, and, having a practical knowledge of the requirements of clean milk production to be able, further, to assist the farmer by personal explanation not only in the production of clean milk, but by bringing home to him the importance of this from the point of view of the firm he is supplying. I have never found these visits to be resented, but, on the contrary, much appreciated.

It is important for the actual buyer to have a thorough knowledge of the laboratory requirements and to work in the closest co-operation with the inspecting bacteriologist. He will then be able to classify his farmers when purchasing, and regulate his price accordingly. Also it will be necessary for him to make independent inspection of the farms from time to time.

We will assume that the milk, having left the farm in the most satisfactory state that conditions will allow, has arrived in the hands of the distributor. It now remains for him to extract by centrifugal force foreign matter that has entered in milking and transit. This should be done by the use of a centrifuge, through which the milk should be passed at Pasteurising temperature. It must not, however, be assumed that by doing so the milk is rendered bacteriologically pure. This is not so. It will therefore be necessary to sterilize it finally, but before doing this the milk must be homogenised by pumping it at a suitable temperature against a cone-shaped agate stone at a pressure of a ton and a half to the square inch. This process breaks up the cream globules

and distributes them through the whole body of the milk, so that they do not rise and form lumps of butter in the necks of the bottles ; it further imparts a rich quality to the milk owing to an even and permanent distribution throughout it. The milk can then be bottled in a narrow-necked bottle and conveyed to the sterilizing ovens, the porcelain swing stoppers having been placed in position without the wire springs attached to them being closed down, which can be done later by a special device after sterilizing, before the oven door is opened. The actual destruction of the bacteria takes place while the air is excluded and contact with human hands avoided. The bottles can now be taken out of the sterilizing ovens and cooled down in shallow tanks filled with warm water, while cold water is gradually added until a temperature of 58 degrees F. is arrived at. During this cooling process, the milk, which during sterilization has reached the top of the bottles, contracts and leaves a vacuum in the intervening space. It will then be found that when the bottle is given a sharp application of the fist at either end, there will be a click caused by a water-hammer knock, which is a very simple test for a customer to make, if he wishes to see that the bottle of milk has not been tampered with during delivery. Immediately the stopper is opened the vacuum is destroyed and when it is replaced, no water-hammer knock will be found to exist. It is a simple precaution to sound each bottle in this way when received, and should be done as a guarantee that the milk has been properly sterilized. Faulty bottles in this respect should be returned. Many people prefer the crown cork to a porcelain swing stopper. I have, however, found in practice the latter to be the most advantageous. Firstly, it can be replaced if a bottle is opened, and prevents flies and dust getting into the unused portion of the milk. Secondly, it can be sterilized, together with its rubber ring, before use, and, thirdly, it is admirable in every way for retaining a vacuum, while very convenient and easy to open.

It has been found that when the above method is adopted, the temperature of the ovens can be raised to 100 degrees C., and retained at that without any injury to the vitamin. If an impartial investigation of published work, etc., be made, the conclusion can only be arrived at that there is no difference in the nutritive value of milk treated in this manner and raw milk. In fact, after most exhaustively investigating the subject, Dr. Janet E. Lane-Claydon, in her report to the Local Government Board with regard to the value of boiled milk as a food for infants and young animals, finally comes to the conclusion, on page 56, part 5, paragraph 2, that " When an animal is fed on the milk of an animal of another species, the milk from which has been found suitable for the purpose, such small differences as have been found in the nutritive value of raw and boiled milk have been in favour of boiled milk " ; and this, apparently, when the precaution was not taken of boiling the milk with the air excluded. Personally, I have never been able to find a single case of rickets having been caused through the use of boiled milk, but do, on the other hand, know of cases

where it has been most beneficial, and also of children who have been unable to take any other kind of milk. In my own experience, in handling over ten million bottles annually, I have never been able to detect any injurious result arising from this treatment, either in every day practice or in the laboratory.

The primary object of sterilization is to keep milk sweet in liquid form for a longer period than is possible by other methods; hence the necessity of taking it to as high a temperature as possible without injury. *B. Subtilis* appears to be one of the most difficult types of bacteria to deal with in this respect, for, even if we assume all types of it to be non-injurious to public health, it is certainly very injurious to the keeping quality of the milk. For example, the following experiment, taken from "Studies on Aerobic spore-bearing non-pathogenic bacteria," by Ford, Laubach, Lawrence, Rice, page 292, may be of interest:

B. Subtilis spores survived $1\frac{1}{4}$ hours steaming at 100 degrees C., and autoclaving at 19 lbs. pressure, but were destroyed when twenty pounds pressure was reached.

It is therefore obvious that if it is desired to destroy this type it is quite useless to go only to 63 degrees C. for thirty minutes. With regard to tubercle bacillus, in a recent interesting paper by Mr. L. J. Meanwell, National Institute for Research in Dairying, on the "Investigation into the effect of Pasteurisation on the bovine tubercle bacillus in naturally infected milk," it was discovered that tubercle bacillus was actually present after the milk had been submitted to 62.8 degrees C. for thirty minutes. The assumption that tubercle bacillus can be destroyed at anything under a 100 degrees C. appears to have arisen through the investigators using cultures instead of naturally infected milk. The following are the final conclusions arrived at in Mr. Meanwell's paper in the *Journal of Hygiene*, Volume XXVI, No. 4, October, 1927, page 402:—

1. A temperature of 62.8 degrees C. (145 degrees F.) for thirty minutes does not invariably kill the tubercle bacillus in naturally infected milk, although in most cases this temperature is effective.

2. At a temperature of 60 degrees C. (140 degrees F.) for twenty minutes tubercle bacilli are in many cases destroyed, but this combination of time and temperature leaves no margin of safety.

It is extremely important to wash efficiently all milk bottles returning to the dairy, and also to steam them thoroughly before they are again put into use. Several makes of bottle-washing machines are now on the market, by which bottles can be washed without the use of brushes. These are all very efficient and are strongly to be recommended, as they prevent contamination from *B. Subtilis* arising from the use of the brushes, which are very often heavily contaminated in this respect when new, and before being put into use. It is also important, of course, that the water used both for washing and final rinsing should be as sterile as possible, especially for the latter, as it is obviously only possible to reduce the bacterial count, after leaving the washing machine, to that of the final rinse water. The final steaming of the bottles should always

be carried out, in order that the milk may be put into as clean a receptacle as possible.

It was found at the recent Clean Milk Course held at the National Institute for Research in Dairying last November, that the influence of unsterile bottles on the sweetness of milk showed an average loss in sweetness caused by the rinsings of washed bottles to be between 12 and 18 hours when compared with milk inoculated with rinsings from sterile bottles. It is also extremely important that all piping and tubes, etc., through which the milk passes in the dairy, should not only be thoroughly washed out and steamed with live steam, but also efficiently sterilized in a sterilizing oven for as long a time as practicable, before they are again put into use. The whole plant should be treated in the same manner not less than three times during the day, otherwise grave sources of contamination will often have been found to have survived cleaning.

In many dairies in this country the practice of cooling the milk after it leaves the sterilizer is omitted and the bottles are allowed to cool down without any artificial aid, the object chiefly being to avoid the cost of further handling, which is considered unnecessary. It would, however, appear questionable, in view of the length of time required for the bottles to become anything like cold, whether this is really an economy. Personally, I prefer the more rapid method of cooling after the milk has left the sterilizing oven. Not only does a better vacuum appear to be obtained by so doing, but also a more palatable flavour; this, however, is largely a question of individual taste. Again, in some dairies the milk is taken in the ovens to considerably over 100 degrees C. I have not, however, found it possible to do so without caramelisation taking place, and consider that this practice cannot be too strongly condemned. Not only is it harmful, but unnecessary. In Europe milk is very often subjected to very high temperatures for purposes of bulk sterilization, the milk being bottled afterwards and a vacuum considered unnecessary, apparently because the milk has been submitted to such a high temperature that the living organisms, and spores are largely destroyed. No doubt this is a much more economical method of sterilizing milk, but, judging from samples that I have received from time to time, it appears to have a somewhat adverse effect on the flavour, the milk having a somewhat brownish tint, apparently from the caramelisation, when compared with milk that has not been so heated. It will appear that, when excessive temperatures are used, it is not necessary to cool the milk so thoroughly and rapidly. Again, milk can be sterilized by boiling it in a rarified atmosphere in much the same manner as that employed in jam-making. This is again a method of bulk sterilization. Another method is by the use of Ultra-violet light. This, however, appears to render the milk somewhat oily in taste and appearance, owing to its causing a chemical change to take place, and it will hardly appear that research has been sufficient in this direction to warrant its application to commercial sterilization.

There has in recent years been a great increase in the use of sterilized milk

in England. Not only has it been marketed by many firms in London, but also in Birmingham, Wolverhampton, Manchester, Bristol, and in many other cities in the provinces. The public evidently recognise it as both a safe and convenient milk supply. In centres where it is largely sold, such as Birmingham and Wolverhampton, a marked reduction in infant mortality has been noticed by medical officers. The report of the Medical Officer of Health for Birmingham, 1926, page 95, states: "There has been a very satisfactory drop in infant mortality in Birmingham during recent years. For the past eight years it has averaged 80.2 per 1,000 infants born, and has varied from 72 to 86 per 1,000."

DISCUSSION.

THE CHAIRMAN said he thought they would all agree that Captain Lane had read a very interesting paper on the work that he was doing, along with others, to encourage the growth of the movement in this country for the production of a cleaner milk. The amount of effort which agriculture and the dairy industry as a whole was putting into the work to improve the quality of the material which they handled was amazing and the results were practical. Personally he thought there was very little doubt but that before many years were over they would be astounded at the change which would take place—indeed was taking place—in the quality of our milk. Captain Lane was one of those who realised the extreme importance of starting his work at the beginning, and of making sure that he obtained the best material. He was one of the pioneers, because it was not everybody who had realised the importance of this matter. He was one of those members of the industry who was making use of all the knowledge that science had now made available and applying it to his own work, and those who had watched its growth in the country could tell them of the astounding change—he spoke advisedly when he used that word—which could be produced in the quality of milk from the regular examination of milk as it came to the depot, wise advice to the farmer from whom it came, and a certain financial advantage resulting from better work. With these three things, Mr. Lane and his colleagues would revolutionise the milk industry of this country. He thought they had every reason to be proud of these men and of the work which they were doing.

LIEUT.-COLONEL H. R. KENWOOD, C.M.G., D.P.H. (Emeritus Professor of Hygiene and Public Health, University of London), said it had given him very great pleasure to listen to the able paper by Captain Lane. It was very interesting and instructive, and he agreed with almost everything stated. He agreed with him in the heating of the public milk supply, of which he (the speaker) had been an advocate for many years. Really, the difference between pasteurization and sterilization was one of temperature; and the heating of milk he was convinced was a matter of very great public health value. He agreed with Captain Lane that the best temperature for sterilising milk was that which was just a shade under boiling point, and he agreed with him that no milk lost in nutritive value when it was heated up to that temperature. All the evidence seemed to him to support that fact in spite of many theories and assumptions to the contrary. He was perfectly confident that such milk suited not only children but the majority of infants, and when it came to those

infants which it did not suit it would probably be found that their number was not greater than that of those whom mother's milk did not suit. He agreed—and he was sure his friend Dr. Stenhouse Williams who had done so much to advocate the necessity of securing clean milk also agreed—with Captain Lane's emphasis on the necessity of clean milk for efficient sterilization. It was even more important for efficient pasteurization. There was only one respect in which he differed from him. He said in the paper "The assumption that tubercle bacillus can be destroyed at anything under a 100 degrees C. appears to have arisen through the investigators using cultures instead of naturally infected milk." He did not know of anything which pointed to the fact that it was only an assumption. Recent work, by the most approved methods, demonstrated that the temperature of pasteurization, which was considerably below 100, was efficient in that respect. Captain Lane had referred to Mr. Meanwell's results, and it was Mr. Meanwell who recently had tested that fact in a series of experiments in respect of 118 guinea pigs, of which 117 remained absolutely free from tuberculosis after the infected milk had been heated to 145° F. for 30 minutes. The positive result of these tests was over 99 per cent., and the one exception he regarded as a "freak" result, because in a long series of bacteriological experiments one got results which were out of tune with the others and which could be ascribed to accident. Mr. Meanwell's results seemed to him to be a magnificent testimony to the value of pasteurization. They surpassed even those of Dr. White, who had pronounced that pasteurization as understood at the present time was an absolute guarantee against the communication of the bovine tubercle bacillus. In his (the speaker's) opinion both pasteurization and sterilization had a public health value and were safe. As a testimony of that, might he remind the meeting of a striking piece of evidence? As they knew, very young children suffered mostly from tuberculosis of the abdominal organs which indicated that infection mostly came by way of the mouth. For many years 25 per cent. of the infection of tuberculosis in infants and young children had been ascribed to the germ in the cows' milk which they drank. One of the most remarkable facts of quite recent years had been the reduction of tuberculosis among infants, and further, the great reduction of tuberculosis of the abdominal organs as compared with that of other organs of the human body. There was, therefore, something in the feeding line which undoubtedly had an influence in that reduction, and in all probability it was mainly due to the advance made in recent years in the heating of the public milk supply. In London the heating of milk was practised more than in any other city in Great Britain; it was estimated by those who knew that about 90 per cent. of all the milk consumed in London had been previously heated. He had taken the trouble to get at the facts in reference to tuberculosis of the abdominal organs of infants in London, and he found that London was much better off than the other large cities, but with respect to tuberculosis of other organs there was not much difference. He took it that that could only be explained on the ground that there was a good deal of infection in the milk given to children and that the reduction of disease in respect of the abdominal organs was brought about by the heating of milk. He congratulated Captain Lane on his useful paper, to which it had been a great pleasure to listen.

COL. J. W. BRITTLEBANK, C.M.G. (Chief Veterinary Officer, Manchester Public Health Dept.) said he had listened with great pleasure to Captain Lane and had also been helped by what Professor Kenwood had said, but he did not believe that sterilization or pasteurization was the aim all and end all of the treatment of milk. He was going to admit at once that these methods were a great public health

expédient for the time being, but he hoped that those associated with the work—and in Manchester they had pushed pasteurization as far as they could and had 90 per cent. of their milk pasteurized to-day—would not lose sight of the very big economic problem behind these expedients which could not be carried out without an additional charge on the industry, and of the fact that the real article they ought to aim at was good, clean, raw milk. The point about which he was concerned was that in taking hold of these expedients they were losing sight of the importance to agriculture of a reduction in the immense amount of tuberculosis in cows. Our herds to-day were probably as fine as any in the world, and it was absolutely incumbent upon the public health men to appreciate that public health was closely allied with that of animals. They could not separate the two. He stood before them as a man who had devoted himself to human public health for the last twenty-eight years, and he was also a veterinary surgeon who had spent his life trying to deal with the animal scourge and endeavouring to get a pure milk supply, and he was not yet discouraged. He thought it was quite within the field of accomplishment. They had had, however, too many ignorant advisers, and in the multiplicity of advice that the country had had British agriculture had been passing through probably the worst time in the history of the oldest of them. He knew of the difficulties of the farmer, and he said that unless they concentrated on the reduction of tuberculosis in animals they could do nothing ahead for agriculture, and be it observed the milk supply could not be separated from true agriculture. Tuberculosis was the key-note of the whole problem, and if they could eliminate this scourge they would eliminate a tremendous percentage of the losses which agriculture suffered in regard to its livestock. In recent years legislation had shown a tendency to become more and more complicated, and to direct itself into water-tight compartments which were of no use to anybody. In 1913 a tuberculosis Order was launched upon this country, but how far had they got? It was, of course, suspended during the war, but it had had a fair test, and because of the lack of proper administration it had to-day effected practically nothing. He did not think it was an exaggeration to say that practically every animal that was removed under that Order had done all the harm it was likely to do. It was never intended that the Order should be allowed to dwindle and become so inefficient; it was intended to be a starting point for an attack on the great animal scourge. He believed that he was justified in saying that almost all the money spent on the administration of the Order was wasted. What was wanted was that the farmer should be treated like the rest of the community who were desirous of the best that could be given. If they would only take him in and ask him to lend a hand they would get magnificent results. They might still find that it was necessary to pasteurize—he believed it would be necessary for many years to come, because the battle they were waging was a gradual one—but he did make a plea that a meeting like that should urge upon the Legislature that the battle of tuberculosis was not fought by merely directing its attention to humanity alone. The tuberculosis of men and animals was the same disease, promoted under the same conditions. What had been done for man in the reduction of tuberculosis could also be done in the animal kingdom, to the immense advantage of those persons concerned particularly with the nation's milk supply. It was not for him to go into the losses incurred. He had in another place read more than one paper on estimates that he had tried to formulate, but the losses were enormous. Out of our 3,000,000 dairy cows at least 1,000,000 were infected with tuberculosis in some form or other, and if they accepted that their depreciation in value on account of this was 10s. a head—surely a modest estimate—they would arrive

at a figure which, if tuberculosis was removed, would be of enormous benefit to agriculture.

MR. CECIL JONES (Editor of *The Dairyman*) said he would like to add his thanks to Captain Lane for his paper, and he hoped that at no distant date he would read another paper there, because that evening quite a number of practical dairy-men were present who were not actual sterilizers of milk and they would have liked to hear more about the process. They were more or less familiar with the homogenisation process, which rather appealed to them—in fact some of them had thought that it would be a good thing to homogenise all their milk so that the fat might be evenly distributed. He did not know whether it was fair to ask Captain Lane in some future paper to state the cost of a homogenising plant to deal with so many gallons an hour, and how many horse-power hours were required to homogenise 1,000 gallons of milk: This information would be very interesting to many people. It was a matter of considerable interest to the dairy trade outside of those people who were sterilizing milk and who knew all about it. Captain Lane had told them that he did not know of a single case of rickets being traceable to the use of milk which had been sterilized. This was a statement which carried them but a very little way. Professor Kenwood had also agreed with Captain Lane that the heating processes did not detract from the nutritive value of milk; but he (the speaker) had a colleague, a very fine physical specimen, and he married a lady who was a very fine specimen of her sex, and they had a child which on doctor's advice was fed on pasteurized milk, which was heated to 150° F. The doctor said it would be all right for the child and that it should have one or two grapes a day. After some months there were distinct sign of rickets. This was a fact which upset a very nice theory. In view of this, one was very distrustful of the statement of any particular medical man to the effect that he had observed a number of babies in a large institution and that he did not see any case of rickets. He agreed that sterilized milk was very useful in that on a voyage to India or Australia it could be taken by a baby, but he wondered whether speaking so much about sterilized milk was not bringing them near the day when perhaps they might be told of the advantages of dried milk from some country where labour was cheap. There was one other point. Captain Lane had quoted Mr. Meanwell as saying that there was no certainty that if milk was pasteurized at 145° F. the tubercle bacillus would be destroyed. That was the point of the paper, and that experimental fact impressed him far more than all the theories of the professors. But Captain Lane went on to say that there was no evidence that the tubercle bacillus could be destroyed below 100° C. He (the speaker) could not see that in Mr. Meanwell's paper, which he had read carefully more than once; but the fact that 145° F. was a dangerously low temperature and that the tubercle bacillus might live at that temperature, provided a complete argument against the process of pasteurizing at the lowest temperature possible permitted by the Ministry of Health.

DR. C. LEONARD WILLIAMS (M.O.H., Barking), congratulated Captain Lane on his admirable paper and remarked that they could not have had a more capable exponent of the point of view he had placed before them. It had been represented that night that if they were to meddle with our milk supply they might as well go the whole hog and find a much better, purer and safer supply than sterilized milk in the form of dried milk, because they could take dried milk ten times round the world and it would be quite safe to take after that journey. Modern progress

seemed to have forgotten what was old history, even at the beginning of the war, and that was that Professor Purvis of Cambridge, associated with another bio-chemist, undertook the physical, chemical analysis of milk after being heated and, to the best of his belief and knowledge, they came to the conclusion without the shadow of a doubt that the physical chemical properties of boiled milk were essentially different from those of raw milk. If they accepted that—and he for one was forced to do so—the onus of proof that milk treated as outlined by Captain Lane was of any worth rested with those who were altering it from the way in which nature had given it, and in this connection there was curiously little evidence. They did have the evidence that a few laboratory animals bred on boiled milk did not seem to show much difference from a similar number bred on raw milk, but with regard to any great experiment on a national scale he knew of no sufficient evidence to show that the altered milk was as good as raw milk. The paper they had heard was of exceptional merit. They had had the best possible presentation of the case. They had had before them for their consideration the infant mortality figures of the city of Birmingham. It had been suggested that the decline showed in these figures was due to an increased consumption of sterilized milk. As a matter of fact, this fact generally had little or no effect on the infant mortality. Indeed, probably the more scientific dresses now worn by prospective and expectant mothers has had a far greater influence on infant mortality than the consumption of sterilized milk. The only thing he asked them to agree to that night was that Captain Lane's case was not proven.

MR. LLEWELYN B. ATKINSON said he was an engineer, and might be thought not to have any information on the subject discussed that night; but he had produced his own family's milk for the last twenty-five years, and he certainly knew a little about the milk business. When he had young children his own solution of the whole problem was to buy young cattle at the first calf from Killarney Kerry cows—which had been reared in the open air and had never been in barns or byres; and he believed it to be a fact that there was no tubercular trouble among these particular cattle. In later years he had kept cattle of other kinds, and like Professor Kenwood, he had been staggered with the enormous mortality from tuberculosis among cows. There was another scourge from which cattle suffered and that was Jones's disease. This also seemed to be transmitted from cows to calves, but whether to human beings he could not say. At various stages in Captain Lane's paper he spoke about sterilizing at 100° C., and then he spoke of boiling. He would like to know just what he meant, because milk did not boil at 100° C., and unless one was careful, the milk at the bottom of the pan would be considerably over 100°. He was quite sure that there was a material difference between milk that had been boiled and that which had not reached boiling point. One speaker had referred to dried milk. What was the difference in cost between sterilized milk delivered to the consumer when one had to carry the water, and dried milk delivered to the consumer who supplied the water? He suspected that the dried milk was the less costly product. To-day the bulk of the milk supply in London in the largest caterers' establishments was dried milk that had been re-compounded with water. Dried milk was also re-compounded on board the steamships on which he had travelled to America. He thought there was an economic question there. It would be said if they drank sterilized milk that it came from a British farm, but he would remind them that it was also coming in a fluid state from the Continent. He had tried dried milk himself to see what effect it would have, but so far he had not discovered any difference. One thing they must realise, and that was that the

complicated method of treating milk was quite beyond the ordinary small farmers who were working perhaps on 50 to 100 acres. They had not the time, skill, intelligence, or capital to deal with milk by these processes; it must be carried to a central creamery if it was to be done. These were some of the points that occurred to him as a result of listening to Captain Lane's paper.

DR. A. P. CAWADIAS said the question of clean milk and of sterilized milk was one of actual necessity. There were children dying from enteritis and tuberculosis brought on by milk. The children must be given milk which did not bring these diseases. It was a fine ideal to destroy completely tuberculosis in cattle, but it was remote. Children could not be left to die while they were endeavouring to reach those ideal years of the future which they all desired. Clean milk was absolutely necessary, and the same could be said of sterilized and pasteurized milk. But did the methods of sterilization and pasteurization make milk noxious from another point of view? He confessed that he did not believe that they did. He had not heard the word "vitamin" mentioned that night. They should remember they were only now beginning to study the vitamin question. He did not think that the sterilization or pasteurization of milk could be said to cause any disease. Let them take rickets for example. Rickets had a multiplicity of causes, and to say that this disease was due to this cause and that cause, or to a deficiency in vitamin D, was to go against the findings of medical research. The case of the child that had rickets and was taking sterilized milk could not be judged medically. There was a too one-sided view of these diseases. He did not think that sterilized milk was noxious, and as clean milk was necessary it was important that such work should be carried on.

MR. J. ANTONY said that after hearing the discussion, he had come to the conclusion that the only safe way to get clean milk was to take the cow to the baby.

MR. G. F. GOSNEZ (National Association of Creamery Proprietors), said it was a much too late hour for him to make a speech, but he wished to congratulate Captain Lane on his excellent paper. His own conviction was that the best way to give milk to children and to adults was in the raw state, provided it was pure and clean. He regarded the milk trade of this country as having one of the highest trusts that it was possible to place on any trade or profession, and he believed that, generally speaking, they were rising to it. During the last few years there had been a marked improvement in the methods of production and distribution. He was not going to say that they were perfect, but they were as near perfection as was possible at this stage. He had had the opportunity of seeing the methods of production and distribution in other countries, and he could say that we had not much to learn from them. It seemed to him that if the public in this country really knew the great skill, care and attention that was given to the production and handling of milk they would be more gratified. His own view was that at the present time it would be criminal to give milk to big cities like London without being processed. He did hope the time would come when there would be no tuberculosis in cattle, and no processing of milk; but he was perfectly safe in saying that never at any time was the milk supply of London better than to-day.

THE CHAIRMAN, before calling upon Captain Lane to reply, remarked that the views expressed at that meeting were exactly what one would expect! Each of the speakers had their own ideas, quite definite, and not one of them could really prove

that the other fellow was wrong. If Dr. Leonard Williams was cross with them for processing milk, he (the Chairman), thought that, if he knew as much about the difficulties of keeping and carrying fresh milk, and the position in which the industry had been left as he himself did, he would agree that for some time to come they would certainly have to continue to process a considerable portion of their milk. He hoped that Dr. Williams would agree with him that in the present state of knowledge the different types of milk ought to be given a fair chance. The quality of our milk was of immense importance, and it was one of those problems that should be studied on a really extensive scale. What was the true food value of the various preparations to young infants they knew not, but if, as a result of that meeting, they did nothing more than stir up things so that they could do their work more efficiently, they would have accomplished a great deal. With reference to Professor Kenwood's remarks, there was no doubt at all that the experiments carried out by Mr. Meanwell upon the viability of the tubercle bacillus in naturally infected milk when heated to 145° F. for half-an-hour, were correct and were not due to any errors made in the course of the work.

CAPTAIN LANE, referring to Professor Kenwood's observations, said that the one guinea pig that died out of the 118 tested by Mr. Meanwell, he regarded as the lost sheep that might have caused all the trouble. Mr. Meanwell's paper laid particular stress on the fact that the cow that provided the milk was one which would have been ordinarily included in a dairy herd which would have supplied milk in the ordinary way. He thought that Mr. Meanwell's paper cast very grave doubts on the work that had been based upon cultures previously, and it should give them cause to think. He did not think there was half enough work being done with naturally infected milk, and the result of Mr. Meanwell's investigations had to a very great extent revolutionised the point of view in regard to the matter. In regard to Colonel Brittlebank's remarks, he did not tell them how they were going to get milk to the European population in the tropical colonies unless it was processed; while in industrial centres like London and other large towns, it would always be an exceedingly difficult matter to get clean milk, unless it was sterilized, and moreover the process of sterilization was convenient, because it provided a supply of milk night or day, which was a great convenience. In September, 1926, there was an outbreak of dysentery at St. Andrews, which was traced to a form of dysentery which had not previously come under suspicion—a milk-borne form of dysentery. The milk supply in question was being got from a farm outside the town, and the probability was that if the milk had been pasteurized the outbreak would never have occurred. It was, of course, very desirable to eliminate all tuberculous cattle, and he would say that about 30 per cent. of the cattle in England were tuberculous. If they destroyed all the cattle suffering from tuberculosis the price of cattle was going to increase, and even if all these cattle were destroyed, it was doubtful whether the disease would be for ever removed, because it might occur again because of conditions under which the cows lived. Mr. Cecil Jones had referred to the homogenization plant. The cost depended on the type and size of the plant; they could be found in advertisements in trade papers. As he suggested, this matter might form the subject of another paper. In respect of rickets, they did not have any details as to the qualities of the pasteurized milk that caused the disease. One thing would appear to arise from this and that was that the Ministry regulations should not be too definite. The temperature in Mr. Meanwell's paper was based upon the minimum temperature for pasteurization. The Ministry had laid down regulations, and what happened generally was that the minimum became

the maximum, and it was rather an instance of how extremely careful the Ministry should be before they got too definite. With reference to Dr. Leonard Williams's remarks, he could only refer him to Dr. Janet E. Lane-Claypon's report to the Local Government Board. That was the most exhaustive work on the subject of the nutritive value of boiled milk, and he knew of nothing that would enlighten them more, although it was fairly old. In reply to Mr. Atkinson, the milk referred to was sterilized milk at 100° C., retaining that temperature for 35 minutes. Personally he had not found it coagulate up to 100° C. On the question of re-constituting powdered milk, he might say that the temperature for this was much higher, and that putting water to milk powder became a nuisance.

THE CHAIRMAN said that Captain Lane and himself would like to offer their sincere thanks to the members of the Society for inviting them there, and he was sure that they all felt grateful to Captain Lane for the care he had taken with his paper and the very interesting evening he had given them.

The meeting terminated with a vote of thanks to the Chairman, proposed by Mr. G. F. Gosnez.

OBITUARY.

VISCOUNT HAMBLEDEN.—Viscount Hambleden died at his residence, Greenlands, Henley-on-Thames, on June 16th, at the age of 59. Born in 1868, William Frederick Danvers Smith was educated at Eton and New College, Oxford. He rowed in the Eton Eight in 1886-7, stroked his college boat for three years, and would certainly have received his "Blue" but for his doctor's orders which forbade him to row in the Oxford and Cambridge boat race. He was a brilliant oarsman and took the keenest possible interest in rowing.

On his father's death in 1891 he was invited by the electors of the Strand Division to contest his father's seat in the Conservative interest. He was duly elected and continued to hold the seat until he retired in 1910.

Soon after leaving Oxford he entered the newspaper distributing firm established by his grandfather, and quickly acquired the detailed knowledge necessary for the management of the business. The removal of the firm's headquarters shortly after the war from the corner of Arundel Street and the Strand to its present position in Portugal Street was closely connected with Lord Hambleden's great interest in hospitals and their work, for when Messrs. W. H. Smith and Son decided to acquire the site of King's College Hospital for their new premises, Lord Hambleden generously presented the hospital with a new site at Denmark Hill. Since that date he has been Chairman of the Hospital and has done much to promote its welfare by his business acumen as well as by personal generosity. But his services to hospitals were not confined to one hospital. He held high office on the governing bodies of many voluntary institutions both in London and in the country. For the past nine years he was Treasurer of the British Hospitals' Association and was also Chairman of the Association's London Regional Committee. He was greatly interested in the provision of wards in hospitals for paying patients, and, as a result of experiments in this direction at King's College Hospital, the trustees of King Edward's Fund decided to take action in the matter. Lord Hambleden was chosen to preside over the Committee appointed to enquire into this question, and their report, when presented, will no doubt be of great value in promoting further progress in this direction. He had been one of the

most valued members of the governing body of Eton since 1902 and was always devoted to the interests of his old school. He and Lady Hambleden gave welcome hospitality at their home at Greenlands, between Henley and Marlow, to many generations of New College oarsmen training for Henley Regatta. The river, indeed, was another of his interests, and he was appointed a member of Lord Lee's Commission on Thames Bridges two years ago. Lord Hambleden was also a Deputy Lieutenant of Devon, in which county he had a house at Moreton-hampstead, as well as Lieutenant-Colonel of the Royal 1st Devon Yeomanry. He served in Gallipoli and Egypt in 1915 and 1916 and was mentioned in despatches on various occasions. He had been a member of the Royal Society of Arts since 1900 and in 1921 contributed a hundred pounds to the fund for the purchase of the Society's house.

NOTES ON BOOKS.

ELEMENTARY CRAFTWORK IN METAL. A. J. Shirley. London: B. T. Batsford, Ltd. 7s.

The very earliest workers in metal known to us were in possession of the fundamental principles of their art. Those remote craftsmen of the Bronze Age laid all their stress on Form. It may be that they were forbidden by religious taboos to represent man and animals, but whether that was so or not they found sufficient scope for their purposes in the creation of abstract designs.

In England and Ireland there have been found, besides swords, shields and other warlike accoutrements, brooches, necklaces and personal ornaments beaten and engraved, and showing admirable taste: all these dating from before the third century B.C. One of the finest bronze shields that we have was found in the Thames at Battersea. It can be seen in the British Museum.

Since, fortunately, it has often been the custom to bury personal ornaments with the dead, much metalwork has escaped the ravages of time—and of man—and can be viewed in museums at home and abroad. The burial places of Greece, Asia Minor and South Russia were rich in gold and silver vases as well as bronzes. And, as Mr. Shirley says, "a proper knowledge of the right use of material and ornament is best acquired by the study of acknowledged good examples."

This point cannot be sufficiently emphasised. We do not want the market to be flooded with objects that are nothing more than "arty and crafty," however competently their makers have availed themselves of modern technique. To quote Mr. Shirley again, students must distinguish between work done by a man who has allowed his "technical skill to outrun his artistic judgment, and the masterpieces which subordinate the technical skill to a proper balance between good taste or form and necessary ornament."

Elementary Craftwork in Metal, however, was written to enable students to acquire technical skill, and it is a very well arranged and exhaustive book, which should be found useful not only by aspirants, but by teachers. Like most books which come from Messrs. Batsford's, it is sensibly and attractively printed.

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.2.

NOTICE.

CANTOR LECTURES.

Owing to a wide-spread demand for early publication, the three Cantor Lectures on "The Scientific Foundations of the Refining of Petroleum," delivered in January, by Dr. A. E. Dunstan, D.Sc., F.I.C., F.C.S., Chief Chemist, Anglo-Persian Oil Co., Ltd., have been printed in pamphlet form (price 3s.), and can be obtained from the Secretary, Royal Society of Arts, John Street, Adelphi, W.C.2. The lectures will be printed in the *Journal* in August.

A complete list of Cantor, Howard and other lectures, which are available in pamphlet form, can also be had on application.

BINDING COVERS FOR JOURNALS.

For the convenience of Fellows and others wishing to bind their annual volumes of the *Journal*, cloth covers can be supplied, post free, for 2s. each, on application to the Secretary.

PROCEEDINGS OF THE SOCIETY.

ANNUAL GENERAL MEETING.

The One Hundred and Seventy-fourth Annual General Meeting for the purpose of receiving the Report of the Council and the Financial Statement for 1927, and also for the election of Officers, was held in accordance with the Bye-Laws, on Wednesday, 27th June, at 4 p.m. SIR PHILIP MAGNUS, Bt., Chairman of the Council, was in the Chair.

THE SECRETARY read the notice convening the meeting, and the Minutes of the last Annual General Meeting, held on July 6th, 1927.

THE SECRETARY then read the following :—

REPORT OF COUNCIL.

I.—ORDINARY MEETINGS.

“ The Royal Society of Arts : its Services to Trade and Training ” was the subject selected by the Chairman of the Council, Sir Philip Magnus, for his Inaugural Address. If he found with Lord Sanderson, a former Chairman of Council, that “ the first impression on a survey of the Society's work is one of some bewilderment at the multiplicity of the subjects with which it dealt in rapid succession or even simultaneously,” Sir Philip contrived to give as clear a sketch as could possibly be compressed into the limits of an hour's address of the Society's activities extending over 170 years. He referred to the early system of awards which did a good deal to develop the trade and commerce of our colonies ; to the encouragement of forestry, which led to the planting of some 50 million trees in the British Isles ; to the rewards granted for meritorious inventions, many of which proved extremely serviceable in promoting industries. But possibly the most valuable part of the address was that dealing with the part played by the Society in the encouragement of technical and commercial education. Himself the senior educationalist of the day, Sir Philip was able to describe the educational movements of last sixty years with all the knowledge of one who has been the principal pioneer in most of them, and his summing up of the Society's share in this important branch of its activities must make his address a very valuable fragment of educational history.

The tremendous difficulties of the traffic problem, which are tending every year to approach nearer and nearer to insolubility, have now become so menacing that the Council decided to devote three meetings to the consideration of various aspects of them. At the first of these Mr. Mervyn O'Gorman read a paper on “ Road Traffic Problems of the Pedestrian.” Perhaps the cardinal point advocated was the regulation of the pedestrian in his own interest, and the proposal that the Minister of Transport should publish an authentic code of Road Customs. Pedestrians were dealt with from two points of view—as passengers on the pavement and as possible victims crossing the street. For those in the former case a brief code was drawn up, urging that they should keep to the left, and thus face oncoming traffic, that they should facilitate the progress of others, and that shop-gazers should keep close to shop-windows and get as little as possible in the way of those who are hurrying to their destinations. The lack of rule for foot passengers on the pavement was probably responsible for their behaviour when crossing a road, and a strong plea was put in for the adoption by pedestrians of agreed signals for “ turn right,” “ turn left,” “ stop,” “ swerve,” etc. Pedestrians and motorists alike were urged to practise courtesy towards each other on all occasions, and there can

be little doubt that if this advice were taken the number of street accidents would be reduced to comparatively trifling figures.

The second paper relating to the traffic problem was read by Professor Leonard Hill, under the title "Overcrowding in Public Conveyances." He dealt mainly with the question of ventilation in trains, trams and omnibuses, and gave in detail the results of observations taken with the help of the katathermometer on ventilation in various public conveyances. He also discussed the atmospheric conditions favourable to the spread of "colds" and similar complaints, and commented on the general tendency to keep railway cars too much shut up and too warm. The contamination of air in tunnels with carbon monoxide was mentioned, and reference was made to the great loss of working power and discomfort which tends to ill-health caused by traffic delays due to fog. In conclusion, Professor Hill expressed the view that a serious cause of overcrowding in trains during the rush hours is the division into first and third class carriages, and he urged the speedy abolition of first-class compartments in local trains.

The third paper connected with the traffic problem was read by Major R. G. H. Clements, the title being "The Evolution of Modern Road Surfaces." The enormous volume of present-day traffic and the weight of many of the vehicles have entirely revolutionised the problems of road construction, and although a great deal of work has been done in connexion with the subject, it cannot be said that conditions have yet approached standardisation. The paper described the various kinds of road surfaces which are in more common use, *e.g.*, tarmacadam, concrete, wood blocks, asphalt, brick, etc. An interesting section dealt with the use of rubber, which appears to have given remarkable results in wearing properties, and has obvious advantages in the way of silencing traffic noise and diminishing vibration. The chief drawbacks to its use are the heavy initial cost and the difficulty of anchoring it to the road foundation—a problem that has proved much more difficult than was at first suspected.

Last autumn there was celebrated in Paris the centenary of the birth of Marcellin Berthelot, who may be regarded as the founder of synthetic chemistry. It was felt by the Council that this event ought not to pass unnoticed by the Society, and accordingly they invited Professor Armstrong to read a paper on the subject. Under the title "Marcellin Berthelot and Synthetic Chemistry," Professor Armstrong gave an exceedingly appreciative account of the man and his work. Extraordinarily gifted by nature in many ways, it seems that he might have made a career for himself as a classical scholar, a philosopher, a physicist or a diplomat. The French Ambassador, who presided at the meeting, spoke of his work as French Minister of Foreign Affairs; but important as this may have been, there can be no doubt that his chief claim to greatness lies in the work which he did on glycerin, turpentine, alcohol, formic acid, carbon, etc.—work which, it is not too much to say, opened an entirely new era in chemistry.

Mr. T. Hedley Barry, in his paper "Malayan Varnish Resins," gave a comprehensive account of a "minor forest product." After beginning with a description of the typical forestry of Malaya, and the work of the Forestry Department, he proceeded to show how the resin is collected from the trees, and how it is washed, graded and packed in the factories. The various species of resin were then dealt with, and their principal characteristics explained.

Moisture is responsible for a great deal of damage to goods stored in warehouses, cold storage or ships' holds. Mr. S. J. Duly, in his paper, "The Damage to Cargo due to 'Ship's Sweat,'" restricted himself to one particular form of this loss. It often happens that canned goods brought to this country via the Panama Canal arrive in a rusty condition, even when the wooden cases in which they are packed are entirely free from blemish. The cause of this phenomenon was investigated by Mr. Duly in the course of voyages to Vancouver and New York, and he came to the conclusion that the remedy lies in the proper regulation of ventilation. Hitherto it has been generally supposed that as much ventilation as possible is desirable in all atmospheric conditions, but Mr. Duly's observations led him to the belief that it is inadvisable to ventilate the hold when temperature is going to rise rapidly. The reason for this procedure was fully explained in the paper, the publication of which should be helpful to shippers of canned goods and shipping companies in averting very considerable losses.

"Methods of Radiant Heating" was the title of a paper by Mr. A. H. Barker, in which he began by explaining the differences between conduction, convection and radiation, and the reasons why radiation places the least strain upon the heat-regulating or thermostatic mechanism of the human body, and is, therefore, the most comfortable and healthy method of heating. He then discussed various kinds of incandescent or luminous radiation possessing short wave-lengths, such as coal, coke or wood fires, gas and electric fires, etc., and on the other hand, methods of "dark" radiation, possessing long wave-lengths, as, for example, wall and ceiling panel heating, and floor heating.

Mr. H. de Koningh's paper, "Enamels, Secular and Ecclesiastic," was divided into two parts. In the first he described the methods employed in enamelling, the kinds of furnaces used and the processes of firing. The second part was devoted to an account of well-known examples, the earliest of which dated from the Mycenaean period. Two of these are quite modern in appearance, though they probably were made not later than 1100 B.C. A great many further slides were shown illustrating the characteristics of Graeco-Scythian, Egyptian, early Celtic, Limoges and other typical styles.

In spite of its ancient foundation—its first charter is dated 1514—Trinity House is little more than a name to the man in the street. It was, therefore, very fitting that its activities should be described by Sir Arthur Clarke in his paper, "Trinity House: its History and its Work." Probably the most

important duty of this great corporation is the lighting of our sea coast—a gigantic task. An interesting account was given of the development of the lights used, from the early coal fire beacon at Dungeness to the 500,000 candle-power light at Eddystone. In addition to this work Trinity House is the chief pilotage authority of the whole kingdom, and all pilots are examined annually with a view to testing their sight and hearing, and their knowledge of any navigational changes in their particular districts. It is also the duty of the corporation to disperse wrecks dangerous to navigation round the coast of England and Wales. This task alone for some years after the war was a formidable undertaking.

A great deal of public interest has been roused by the discoveries resulting from the work conducted by the joint mission of the British Museum and the Museum of the University of Pennsylvania in excavating the ruins at Ur. Dr. H. R. Hall, who was himself responsible for the first excavations, read a paper entitled "The Excavations at Ur—1919 to 1926." He showed a large number of slides illustrating the site of the Temple of the Moon God, and many trophies which had been unearthed there, including a great copper relief (now in the British Museum) of a lion-headed eagle seizing two stags, which is one of the most important relics of Babylonian art, dating probably to about 3100 B.C. The paper was intended to summarise the work done up to the end of 1926, and as an introduction to the consideration of the very remarkable finds of this year, which it is hoped will be on view at the British Museum during the present summer.

"Industry Fifty Years Hence" was the title of the paper in which Mr. Archibald Crawford indicated the direction in which he believed the industrial world is now advancing. After a long struggle between capital and labour he thinks that a time has been reached when each appreciates the necessity to himself and to the country of the other. The General Strike did a very great deal to clear the air, with the result that the relations between employers and employed are now more harmonious than they have ever been since the Industrial Revolution. The idea of partnership between the two is steadily growing, and instead of antagonism there is an increasing tendency towards co-operation. After pointing out the immense improvements in the conditions of the working classes during the last fifty years—improvements which have been largely won by the trade unions—he expressed the belief that in another fifty years the functions of the Trade Unions will be benevolent rather than militant, and that the fighting energy of employed and employer alike will be diverted to combating such enemies as illness and unemployment rather than each other.

Astronomic figures are apt to prove bewildering to the lay mind, but probably none more stupendous were ever put forward than those suggested by Dr. J. H. Jeans, who delivered the Trueman Wood Lecture on "The Wider Aspects of Cosmogony." The evidence of geology and of radio-

activity in rocks shows that the earth must be something like 2,000 million years old, and a million million years hence, so far as can be seen at present, the sun will be much the same as now and the earth will still be revolving round it, and this in spite of the fact that the sun is wasting at the rate of 360,000 million tons a day. The number of stars in the universe is estimated at $(2 \times 10)^{24}$; in other words, the same number of grains of sand spread over the whole of England would make a layer hundreds of yards in depth, while as for the immensity of space, some conception of it may perhaps be obtained from the statement that light, which can travel round the world in the seventh of a second, would probably take something like 100,000 million years to travel round the universe. .

The scientific cultivation of rubber can only claim to be about a generation old, and it is therefore natural that great developments should have taken place in it during recent years. Thirty years ago, for instance, the model planter kept the ground between his trees as bare as possible; now it is considered essential to preserve the top soil by a copious cover, preferably of leguminous plants. An admirable conspectus of present-day practice was given by Mr. Charles Herbert Wright, in his paper, "Modern Aspects of Rubber Cultivation," in which he dealt fully with such questions as soil conservation, drainage, tapping systems, manuring and methods of improving strains. The paper was the outcome of five years' close study of the science of rubber growing and experience acquired on the plantations.

There are few departments of civilised life in which greater advances have been made in recent years than in illumination. Mr. Henry D. Wilkinson, in a paper entitled "Theatre Lighting," described the apparatus now usual in first class theatres. The lighting effects now obtainable on the stage are often extremely beautiful, and in order to secure them exceedingly elaborate machinery is required. The enormous amount of current used has also led to remarkable developments in its control and regulation, while notable improvements have been made in the factor of safety. In present-day practice all resistances liable to become heated are housed in fire-proof and well-ventilated chambers. Mr. Wilkinson illustrated his paper with a number of demonstrations, among the most remarkable being a series of effects of moving clouds.

"The Lead Acid Cell: its Place in Modern Industry," was the title of a paper read by Mr. Harold G. Brown. For about seventy years this cell has had an importance of its own, for two reasons: firstly, because, being mechanically and chemically reversible, it could be used to store the energy produced by primary cells, and, secondly, because its internal resistance was so low that enormous currents could be drawn from it without reducing its voltage to insignificance. At the present day its use in industry is very great and is steadily increasing. It is indispensable in small domestic electric plants, and it is largely used in central station batteries. One of its chief

individual users is the Post Office, whose total capacity of installations will, it is estimated, increase in the next five years from the present 28,500 k.w. hours to 76,350 k.w. hours. Other important uses of the cell are for the electric lighting of trains, automatic signalling, submarine work, road transport and tunnelling and excavation operations; and it will probably remain for many years to come our principal means of storing electrical energy.

In 1894 a course of Cantor Lectures on "Typewriting Machines" was delivered by Mr. Henry C. Jenkins. Since that time a great deal has been done to improve the typewriter, and an account of this development was given by Lieut.-Commander R. T. Gould in a paper entitled "The Modern Typewriter and its probable future Development." He described in detail the characteristics of all the principal machines which have been in use since typewriters were invented, and his paper was illustrated by a large selection of the best known instruments now on the market. Excellent as many of these are, there seems to be still room for improvement, especially in the direction of speed and noise. Lieut.-Commander Gould spoke of a possible future for an electrically-driven typewriter in which electric power would be used to do the "donkey work"; while with regard to noise, although some comparatively silent machines are obtainable, a good deal remains to be done to improve the mechanism.

Mr. Alfred C. Bossom, in his paper, "American Architecture," related the history of the skyscraper. This began in 1884, when an architect named Buffinger, of Minneapolis, applied for a patent for a steel construction building twenty-eight stories high. The earliest skyscrapers were undoubtedly eyesores, but a tradition was gradually evolved, and, as Mr. Bossom's slides demonstrated, some of the more recent structures are impressive on account of the idea that they give one of strength and harmonious design. Mr. Bossom is himself the architect of a number of these. He is not, however, an advocate of this style of building, except in its proper surroundings, and he took pains to make it clear that in his opinion the skyscraper is absolutely unsuitable for the British climate. In the second portion of his paper Mr. Bossom described American methods of building and explained how they enable work to be carried on far more rapidly than in this country, and how scientific organisation enables the operatives to receive higher wages, the contractors larger profits, the building owners a greater return on the capital invested, and the tenant to pay a lower rent.

"The Education and Training of the Blind" was the title of a paper read by Dr. J. M. Ritchie. The idea of training the blind and teaching them to be useful and self-supporting citizens is quite a modern development. A hundred and fifty years ago nothing was done for them, and beggary was generally regarded as the natural field for the blind poor. The first school for the blind in the world's history, *L'Institution Nationale des Jeunes Aveugles*, was opened in Paris in 1784, and seven years later the first British School

was opened at Liverpool. Now, thanks to the devoted labours of many friends of the blind, we have quite a large number both of charitable institutions governed by private committees and of schools maintained by local authorities. The general object of those engaged in teaching the blind is to reduce the differences between their pupils and sighted children to the lowest possible degree. They are taught various kinds of exercises and games to keep them physically fit, and the blind school curriculum closely resembles that of a sighted school. A great deal is now being done to continue the education of the blind after they have left school, and specialised workshops for blind operatives are maintained all over the country. They are carried on under the supervision of the Ministry of Health and grants are paid to institutions which conduct such workshops. With the aid of these the blind man or woman has a reasonable chance of learning a trade or profession and of becoming a self-supporting and self-respecting citizen.

When the advantages of standardisation are being urged, it is often counter-claimed that it hampers progress. Mr. William Taylor, in his paper "Standardisation in Apparatus for Science Teaching," pointed out that it is only when standardisation is misapplied, or overdone so that it becomes systemisation, or when it is not based on scientific principles, that it has this danger. During the Great War those who were called on to manufacture instruments for gunnery, telescopes, sights, range finders, etc., were greatly hampered by the lack of standardisation. Thus in the designs of one of the Services alone there were embodied objectives of more than 200 different focal lengths, although it was found that the whole field could be covered by using 17 focal lengths. A striking illustration of what can be achieved by reasonable standardisation was given in the array of optical instruments constructed from a series of seven lenses, one prism, four slips of glass, three mirrors, a plain and a ground glass and a few standardised mechanical elements. By combining these simple parts in different ways, more or less on the principle of "Meccano" toys, Mr. Taylor was able to produce an enormous variety of optical instruments. Up to the present these parts have not been made in any considerable quantity, but if once they were so produced the price would be very small indeed, and it would be possible to provide schools with quite good optical apparatus at a trifling sum.

A pure milk supply is one of the most important factors in promoting public health, and the arguments in favour of sterilization as against pasteurisation, were admirably set forth by Captain R. W. Lane in a paper entitled "The Sterilization of Milk." In the sterilization process, milk is heated to 100°C., and kept at that temperature for twenty-five minutes, while in pasteurisation milk is heated to 63°C. only (or 145° F.), and retained at that temperature for thirty minutes. It is claimed for sterilization that while it destroys all pathogenic organisms, it does not injure the vitamin or appreciably affect the nutritive value of the milk. Sterilized milk has the further advantage that it will

keep sweet for as long a time as two years, and can therefore be taken for use on long sea voyages to India or Australia. Captain Lane enumerated and described the various processes necessary for securing efficient sterilization, *e.g.*, testing the acidity and bacteriological content of the raw milk, the periodical inspection of the farms from which the milk supply is drawn, the homogenisation, heating, bottling, and cooling of the milk, and the frequent steaming and sterilizing of all piping and tubes through which the milk passes in the dairy. In conclusion, Captain Lane referred to the increasing use of sterilized milk in large provincial towns, as well as in London, which he claimed was an important factor in the reduction in infantile mortality which has taken place in recent years.

A number of important questions connected with the designing of motor vehicles were discussed by Mr. W. Worby Beaumont, in a paper on "Modern Motor Car Design." While deprecating the present taxation of motor cars on the basis of horse-power, he did not think that this had to any large extent brought about limitation of design, though it had undoubtedly stimulated ingenuity and invention in the direction of producing engines of small size and high efficiency. This development, while good in itself, had certainly led to our manufacturers' neglecting to cater for the special requirements of the Dominions and Colonies, where a larger engine was not objected to, provided that it was of high power and did not need much changing of gears. Mr. Beaumont deplored a certain stagnation and standardisation of design, and criticised in particular the low centre of gravity, which is now fashionable, as being responsible for a number of defects, including wheel wobble or "shimmy." After examining these defects in some detail, Mr. Beaumont concluded by referring briefly to some other aspects of motor car design, such as needlessly expensive torque and propeller shaft arrangements, and the unnecessary size and weight of front-wheel brakes, to which exception could also be taken.

II.—INDIAN SECTION.

Six papers were read at meetings of the Indian Section during the Session. In a paper on "Indigenous Indian Banking," Mr. M. M. S. Gubbay described the nature and scope of the banking operations carried on by the Indigenous Joint Stock Banks with rupee capital and local management, and by the private Indian banker—the Shroff, Chetty, or Mahajan—working on his own account, and outside the provisions of the Companies Acts. Mr. Gubbay gave a clear picture of the conditions governing indigenous banking in India, and explained how, owing to the difficulty of connecting any particular consignment of produce with a particular advance and of hypothecating it as security for a loan, it was rarely possible for up-country bankers to obtain any other security for advances beyond the general credit position of the borrower. From this two consequences resulted: (1) that the branch banks, unable to find suitable employ-

ment on the spot for the deposits collected up-country, were compelled to utilise these funds at the large commercial centres at the ports in the ordinary financing operations of international trade, and (2) that the bazaar rates demanded by the Indian private banker were exceedingly high. In conclusion, Mr. Gubbay expressed the view that any change in the direction of making the bazaar "hoondie" a more suitable investment for banking funds would at best be slow in coming, and that any survey of banking conditions, such as was recommended by the Royal Commission, would necessarily include the study of the means for broadening the channel between the bazaar and the banks, and of securing that credit operations throughout the whole system may respond to the policy of the Central Banking authority.

The acceptance by the first Indian Legislative Assembly on February 16th, 1923, of a Government resolution, based upon the Report of the Indian Fiscal Commission, and recommending the adoption of a policy of Discriminating Protection, together with the establishment of a Tariff Board to advise the Government as to particular measures of Protection, made a notable landmark in the economic history of India. In 1924 the Tariff Board, after an exhaustive investigation into steel trade conditions both in India and Europe, recommended the imposition of protective duties upon certain kinds of steel—with the proviso that such duties should be subject to revision at the end of three years. The proposed duties, with the exception of those on agricultural implements, were accepted by the Indian Legislative Assembly, and the fact that the revision of the duties had recently been carried out at the end of the three years period lent a special interest to Sir David Chadwick's paper on "The Work of the Indian Tariff Board," in which he explained the Board's general procedure and reviewed its operations in special relation to the Indian steel industry.

"The Indo-European Telegraph Department," was the subject of a paper read by Mr. Maurice G. Simpson, the Director-in-Chief of the Department. Mr. Simpson described how, after protracted negotiations with the Turks, the construction by them of the line from Constantinople to Baghdad and thence to Fao on the Persian Gulf was begun in 1859, and completed in 1865, a land line from Karachi to Gwadar, and a submarine cable up the Persian Gulf from Gwadar to Fao being simultaneously constructed by the Government of India, to connect with the overland line from Constantinople. Soon afterwards, in 1870, two additional telegraph routes to India were opened, that of the Indo-European Telegraph Company from London to Teheran via Germany, Russia and Persia, and of the Indo-European Telegraph Department on from Teheran to Karachi via Bushire, and, secondly, the submarine telegraph of the Eastern Telegraph Company from London to Bombay. In 1878 the Eastern Telegraph Company, the Indo-European Telegraph Company and the Indo-European Telegraph Department, entered into a working arrangement, and the co-operation then established has continued down to the present time. The recent developments of "beam" wireless made Mr. Simpson's survey of the position of the older land and submarine lines one of exceptional interest.

The subject selected by Sir Edward Gait, who delivered the Sir George Birdwood Memorial Lecture, was "Ancient Bihar and Orissa." The *diwani* of Bengal, Bihar, and Orissa, was granted to Clive by the Mughal Emperor, Shah Alam, in 1765. Bihar and Orissa, which remained incorporated with Bengal from 1765 to 1911, were at the latter date constituted as a separate province containing the three sub-provinces of Chota Nagpur, Bihar, and Orissa. The materials available for constructing an authentic account of early times vary in the case of each of the sub-provinces. Historical records are practically non-existent for Chota Nagpur, though this territory is exceptionally rich in pre-historic antiquities—neolithic and palaeolithic implements and cave-paintings similar to those made by Aurignacian man in the limestone caves of South-west Europe. Orissa is specially noteworthy for its great temples of the early mediæval period, though historical information is in this case also very deficient. On the other hand we know more about the ancient history of Bihar—the centre of the great empires of Chandragupta and his grandson King Asoka—than of any other part of India, and Sir Edward Gait outlined the history of the various dynasties which successively ruled at Pataliputra, or at one or other of the cities of Bihar. He concluded his lecture with some remarks on the history of the modern city of Patna since its foundation in 1538 by Sher Shah, the Afghan Emperor of Hindustan.

The question of the air communications of the Empire is one of increasing importance, and a considerable portion of this field was touched on in the paper read by Lieut.-Col. I. A. E. Edwards, on "The Air Routes of India." After indicating the various actual or potential air routes from Great Britain across Europe to Mesopotamia and India, and thence on to the British and Dutch East Indies and Australia, as well as to Hong Kong, Shanghai and Japan, Col. Edwards proceeded to discuss the means of developing air traffic, and pointed out the great saving in time and money resulting from the transport by air of shipping documents, bullion, and in general, of commodities of high value and small bulk. The roles of airship and aeroplane on long distance routes are, in Col. Edwards's view, complementary to each other, the aeroplane acting as a traffic feeder to the "non-stop" airship, and the much discussed question of aeroplane versus sea-plane was also touched on. He then described some possible main lines of internal air communication in India, and in this connection enumerated some of the material requisites for the establishment of a permanent air route. In conclusion, Col. Edwards referred to the recent development of air survey, which has proved to be a method of great value and importance for many purposes.

An examination of the special problems presented by the situation of the Port of Calcutta on the Hooghly in relation to the outflow from the river and the strong tides from the Indian Ocean, and a description of important improvements now being carried out, are contained in a paper entitled "The Port of Calcutta and its Post-War Development," by Mr. S. C. Stuart-Williams.

Even before the War the available accommodation in the Port of Calcutta had been definitely overtaken by the demands of trade, and a Committee of Enquiry appointed to investigate the position, which presented its report in 1913, recommended a detailed scheme of expansion involving the expenditure of many millions sterling. This scheme, which was approved by the Administration, was for the construction of a new dock system in Garden Reach, to be preceded—in order to meet urgent requirements—by five riverside berths along the river front, behind which the new dock system would lie. During the war the type of construction, *i.e.*, by means of large monoliths, was decided upon, and the construction work, which was commenced three or four years after the end of the war, will, it is expected, be completed early next year. In concluding his paper, Mr. Stuart-Williams expressed the belief that in the new King George's Dock shortly to be opened in Garden Reach, the Port Commissioners were making wise and adequate provision for a trade which was certain to expand and the limits of which it was difficult to foresee.

III.—DOMINIONS AND COLONIES SECTION.

Four meetings of the Dominions and Colonies Section were held during the Session.

Lord Lovat dealt with a subject of special interest in these times in a paper entitled "Migration in the Empire." After a short historical review of emigration from these islands in former times, and of the more recent developments culminating in the establishment of the Oversea Settlement Committee in 1919, and the passing of the Empire Settlement Act in 1922, Lord Lovat proceeded to discuss the somewhat difficult problems which surround the subject, and described the various ways in which migration is being assisted at the present time. In conclusion he paid a tribute to the valuable work which is being done by the 36 voluntary Emigration Societies, which work in co-operation with the Oversea Settlement Committee.

In the session of 1926-7, a paper on Spanish Morocco was read by Señor Don Thomas Baldasano, and this was followed up this session by a lecture by H.E. the Spanish Ambassador on the visit of the King and Queen of Spain to Morocco after the subjugation of the Riff tribes. His Excellency referred to the great progress which has been made by the Spanish Government since the submission of the Riff in the construction of roads, railways, telegraphs, ports, and other public works, in the establishment of schools and hospitals, and the promotion of agriculture. The description of present conditions in Morocco given in the lecture, which was illustrated by a film taken under the direction of the Spanish military authorities, conveyed a clear impression that after the troubled times of the last few years, a new era of peaceful and prosperous development is now beginning in Morocco.

The recent discoveries of Sir John Marshall at Harappa and Mahenjo-Duro in

the Indus Valley, and the establishment of a connection between an ancient Indus civilisation and the Sumerian civilisation of Ur of the Chaldees, have greatly stimulated general interest in archæological matters. "The Ancient Civilisation of Ceylon" was the subject of a paper read by Sir Montagu Burrows, who, after explaining that reliable historical information concerning early times in Ceylon was practically non-existent, proceeded to piece together the current, though often contradictory, Sinhalese legends to form some sort of historical outline. Certain facts, however, appear to be fairly well established, such as an Aryan invasion of Ceylon from India about 540 B.C., and the existence of a connection between the ruling family of Ceylon and the great Chandragupta, King of Magadha, and his grandson King Asoka, to whose missionaries the conversion of Ceylon to Buddhism was due. The interest of the paper was considerably enhanced by lantern slides of the interesting and beautiful ruins of the "buried cities," Anuradhapura and Polonnaruwa.

A paper on "The Gambia Colony and Protectorate" by Sir Cecil Armitage was one of a series of papers on African territories which have been read from time to time during the last few years. After a short historical outline, in the course of which he referred to the description of the Gambia river in the "Periplus" of Hanno, the Carthaginian, and to the Portuguese, Dutch, French and English adventurers, who disputed the trade of the West Coast from the 15th to the 17th centuries, Sir Cecil proceeded to indicate in general outline the chief events of the 18th and 19th centuries. During the 18th century the commerce of the Gambia was controlled by the Royal African Company, which enjoyed great prosperity from the trade in slaves, gold, ivory and beeswax, until the Act of 1807, abolishing the slave trade, brought this era to a close. The 19th century witnessed a retrograde movement in British Colonial policy, and the withdrawal in favour of France of the British claim to the watershed of the Gambia in 1887, and a further concession made in connection with the Newfoundland Fisheries dispute, have resulted in the present restricted limits of the territory. In conclusion, Sir Cecil referred to the increase in agricultural production which has resulted from the establishment in 1924 of an Agricultural Department—and to the educational work carried on by Missionary Societies.

IV.—CANTOR LECTURES.

The first series under the Cantor Trust was a course of four lectures, entitled "Alloy Steels, their Manufacture, Properties and Uses," by Professor H. C. H. Carpenter. After a brief historical introduction, some particulars were given of the statistics of production, and then attention was drawn to the principal alloying metals used, such as tungsten, cobalt, chromium, manganese, etc. The various uses and properties of steel as combined with any one, two, or three of these metals were discussed, and the most modern methods of manufacture were fully described.

In 1886 Sir Boverton Redwood delivered a course of Cantor Lectures on

"Petroleum and its Products," which came to be recognised as a classic work on the subject. The Council felt that, in view of the enormous developments which have taken place in connexion with the oil industry since that date, it was desirable to have a further series. This was delivered by Dr. A. E. Dunstan, who gave a course of three lectures entitled "The Scientific Foundation of the Refining of Petroleum." A short historical retrospect was followed by a discussion of the chemical and physical nature of petroleum, natural gas and its treatment, and the methods of distillation. In the second lecture Dr. Dunstan dealt with the refining of motor gasoline, kerosene, waxes and lubricating oils, and in the third with the cracking of gasoline, finally devoting some attention to the synthetic chemistry of petroleum.

"Fatigue Phenomena, with special reference to Single Crystals" was the title of the third course by Dr. Herbert John Gough. What happens when a metal fractures under various conditions, *e.g.*, impact, corrosion and so forth? The lecturer examined the changes in micro-structure that take place as the result of fatigue phenomena in crystalline substances, and after describing the structure of various metals, explained how fracture is caused by "slip planes." He discussed in some detail the characteristics of deformation of single crystals (such as zinc, aluminium, tungsten, brass, iron, etc.) under static forces, and concluded by stating the present position of the theory of the fatigue of metals.

V.—DR. MANN LECTURES.

It is only in quite recent times that serious scientific study has been devoted to the problem of the acoustic properties of buildings. Hitherto the architect has designed his hall, church or chamber without reference to this point and has trusted to luck as to whether speech or music could be heard in it. Consequently quite a number of our important public buildings are deplorable in this respect. Lately, however, a good deal of attention has been given to this point—notably in America, and at the National Physical Laboratory—and as a result of this work it is now possible for an expert to foretell the acoustic properties of a yet unbuilt hall from a plan or model. The main points of these enquiries were summed up by Mr. A. G. Huntley in a course of three lectures delivered under the Dr. Mann Trust, on "Applied Architectural Acoustics." In these he defined the requirements of good acoustics, and discussed the nature of echo, reverberation and resonance. The uses of the ripple tank and spark method were described; the effects of different materials on sound were carefully explained, and finally the acoustic difficulties in certain well-known buildings were reviewed, and the methods by which they have been overcome.

VI.—DR. MANN JUVENILE LECTURES.

Under the Dr. Mann Trust, Professor Arthur Smithells delivered two Juvenile Lectures on "Flame." After illustrating the means of obtaining

fire in the most primitive ways, *e.g.*, flint and steel, tinder, and the sulphur match, he explained the structure of ordinary flames, their shape and hollowness. Passing then to coal gas flames he demonstrated the nature and action of the Bunsen burner, and showed a number of very beautiful experiments with his cone-separating apparatus. In the second Lecture he passed to the blow-pipe flame and the oxygen-coal-gas flame, and a demonstration was given of the cutting of a half-inch steel plate. The use of gas mantles and the methods of their manufacture were explained, and it was shown how a flame could be sensitive to sound and how it could be made to produce musical notes.

VII.—ALBERT MEDAL.

The Albert Medal of the Society for the current year has been awarded by the Council, with the approval of the President, H.R.H. the Duke of Connaught, to Sir Ernest Rutherford, O.M., LL.D., D.Sc., F.R.S., "for his pioneer researches into the structure of matter."

VIII.—MEDALS FOR PAPERS.

Eleven silver medals have been awarded for papers read before the Society during the current session—six for papers read at Ordinary Meetings, three for papers read before the Indian Section and two for those read at meetings of the Dominions and Colonies Section.

The awards are as follows :—

Papers read at the Ordinary Meetings :—

S. J. Duly, M.A., Head of Department of Commercial Products, City of London College, Mitchell Student for 1925-6, "The Damage to Cargo due to 'Ship's Sweat.'"
Major R. G. H. Clements, M.C., M.Inst. C.E., "The Evolution of Modern Road Surfaces."

Charles Herbert Wright, B.A., "Modern Aspects of Rubber Cultivation."

Alfred C. Bossom, F.R.I.B.A., "American Architecture."

William Taylor (of Messrs. Taylor, Taylor and Hobson, Ltd.), "Standardisation in Apparatus for Science Teaching."

Captain Reginald Willington Lane, "The Sterilisation of Milk."

Papers read before the Indian Section :—

M. M. S. Gubbay, C.S.I., C.I.E., "Indigenous Indian Banking."

Sir David T. Chadwick, C.S.I., C.I.E., "The Indian Tariff Board."

S. C. Stuart-Williams, M.A., Chairman of the Commissioners of the Port of Calcutta, "The Port of Calcutta and its Post-War Development."

Papers read before the Dominions and Colonies Section :—

His Excellency the Spanish Ambassador, G.C.V.O., LL.D., "The Djebala and Riff Country of Morocco" (with cinematograph illustrations).

Sir Stephen Montagu Burrows, C.I.E., "The Ancient Civilisation of Ceylon."

For many years it has been the practice not to award medals either to members of the Council or to persons who had already received a medal for a paper read in a previous year. The Council were therefore precluded from considering the following papers:—

Professor Leonard Hill, M.B., F.R.S., Hon. A.R.I.B.A., "Overcrowding in Public Conveyances."

Professor Henry E. Armstrong, LL.D., Ph.D., F.R.S., "Marcellin Berthélot and Synthetic Chemistry."

Captain Sir Arthur Clarke, K.B.E., "Trinity House: its History and its Work."

W. Worby Beaumont, M.Inst.C.E., M.I.Mech.E., M.I.E.E., "Modern Motor Car Design: some Criticisms and some Suggestions."

Lord Lovat, K.T., K.C.M.G., K.C.V.O., C.B., D.S.O., "Migration in the Empire."

The Council, however, desire to express their high appreciation of these papers.

IX.—FUND FOR THE PRESERVATION OF ANCIENT COTTAGES.

The general fund for the Preservation of Ancient Cottages now amounts to £5,836. Of this sum, £1,525 has been received from Mr. James H. Hyde, for whose generous support of the movement the Council desire to express their special thanks.

Mention was made in the last Annual Report of the gift by Mrs. T. T. Greg, of Coles, Buntingford, of the cottage known as "Buttonsnap," West Mill Green, Herts, once the property of Charles Lamb. A small local committee has been formed under the Chairmanship of Sir Arnold Wilson, who are charged with the duty of looking after the property.

The Council were largely instrumental in saving the three well-known Thomas à Becket cottages, near Worthing, which were in great danger of being demolished. A timely advance of £600 from the Society's Fund enabled some local residents to buy in the property; a public meeting was called at Worthing by the Mayor, and addressed by Sir Frank Baines; a subscription list was started, and it is hoped that about £400 of the money advanced will be repaid to the Fund. The cottages, which are very beautiful and interesting specimens in excellent preservation, have been handed over to the Sussex Archaeological Trust, who will maintain them permanently as dwelling-houses.

The group of eight cottages known as Arlington Row, Bibury—described by William Morris as "the loveliest village in England"—have been offered to the Society at a small figure. They are, unfortunately, in need of considerable repair, the cost of which is estimated by the Society's architect at about £1,000. An appeal for £2,000, signed by influential supporters, has been widely circulated in the press and privately, and it is hoped that it will be possible at an early date to take over the property.

It is proposed to call the first Annual Meeting of supporters of the Fund in the autumn, when a full report will be submitted together with lists of sub-

scribers. This will be published in the *Journal* shortly after the meeting has been held.

X.—THOMAS GRAY MEMORIAL TRUST.

Under the Thomas Gray Memorial Trust, the objects of which are "the advancement of the science of navigation and the scientific and educational interests of the British Mercantile Marine," the Council have offered the following prizes :—

(i) A Prize of £100 to any person who may bring to their notice a valuable improvement in the Science or Practice of Navigation proposed or invented by himself in the years 1927 and 1928.

In the event of more than one such improvement being approved, the Council reserve the right of dividing the amount into two or more prizes at their discretion.

Competitors must forward their proofs of claim on or before December 31st, 1928.

(ii) A Prize of £50 for an essay on the following subject :—

"The Practice of Navigation in the Mercantile Marine."

The essay must be based on the actual methods used by the writer during his career, with special reference to the instruments used as aids to navigation, and the effect of stowage of cargo on the steering, speed and safety of the vessel.

Competitors must send in their essays not later than December 31st, 1928.

The Council have further offered the following prizes to the best students of Navigation in the schools mentioned below for the year 1927-8 :—

Three prizes of £10 each to the Nautical College, Pangbourne ; *Conway*, Birkenhead ; *Worcester*, Greenhithe.

Four prizes of £5 each to *Arethusa*, London ; *Warspite*, London ; *Indefatigable* London ; *Mercury*, Southampton.

In order to stimulate further the study of navigation, the Council have offered a Thomas Gray Memorial Prize of £30 to be competed for by the best students of the Nautical College, Pangbourne, the *Conway* and the *Worcester*.

The Committee are at present considering other ways in which they may carry out the objects of the Trust, and they hope to submit recommendations to the Council at an early date.

XI.—ANNUAL COMPETITION OF INDUSTRIAL DESIGNS.

The fifth Annual Competition of Industrial Designs will be held at the Imperial Institute in July, by kind permission of the Director.

The competition is again being held in the following sections :—(1) Architectural Decoration ; (2) Textiles ; (3) Furniture ; (4) Book Production ; (5) Pottery and Glass ; and (6) Miscellaneous. The prizes offered in all the sections amount to over £1,600. Among the new features of this year's competitions are the Art Congress Studentship of £50, which may be awarded at the discretion of the judges to any candidate whose work suggests that he (or she) is in a position to profit by it, and which may be used by the

winner for the purpose of studying in museums, or going abroad for a short time, or for buying books or other articles that may be of use to him (or her) in his (or her) work ; and a Travelling Scholarship of £100 offered by Mr. James H. Hyde to candidates in the sections of Architectural Decoration and Textiles. A number of well-known firms have again offered very substantial prizes for designs in various sections.

It has always been the aim of the Council and of the various committees appointed by them to carry out this competition to ensure that any designs approved by them should bear evidence that the designers possess not only exceptional artistic ability, but also a sound and practical knowledge of the materials and processes of their trades. The committees consist mainly of representatives of important manufacturing and commercial firms, and the judges nominated by them are careful to see that approved designs are suitable for the materials for which they are intended.

After the awards have been made, a number of selected designs will be exhibited at the Imperial Institute ; probably also exhibitions will be held at suitable centres outside London, where the designs will be brought to the notice of manufacturers likely to be specially interested in them.

As soon as the judges have completed their work, it is proposed to issue, as formerly, a full report on the Competition, which will be published in the *Journal*, and circulated widely among manufacturers and competitors.

The Council have opened a Bureau of Information at which are kept the names and addresses of those candidates at the Annual Competition of Industrial Design whose work has been accepted for exhibition and who desire to obtain *bona fide* employment as designers. Although no guarantee of employment can be given, the information is placed at the service of manufacturers in search of designers.

A certain number of appointments have been made in this way, and a good many designs have been sold at the exhibitions.

XII.—EXAMINATIONS.

The various new examinations instituted in 1927 have been continued this year, and examinations are now held at Easter, Whitsuntide and in July, while special sets of group examinations are conducted, at the request of the London County Council, for L.C.C. Junior Commercial and Junior Technical Institutes, and a further set of examinations is held for students at Day Schools. The total number of entries this year is just over 100,000—a notable landmark in the history of the Society's examinations, which began in the year 1854, when a single candidate presented himself for examination at the Society's House. A full report on the Examinations will, as usual, be published in the *Journal* at a later date.

The liberality of the Worshipful Company of Clothworkers has enabled the Council, as in past years, to offer the usual silver and bronze medals. These

medals are greatly valued by the successful candidates, and they contribute not a little to maintain the high standard of the examinations.

XIII.—ORAL EXAMINATIONS IN MODERN LANGUAGES.

The Oral Examinations are still in progress in various parts of the country. Particulars will be given in the annual report on the Examinations.

XIV.—NEW COUNCIL.

The Vice-Presidents retiring under the ordinary regulations are : Sir Charles H. Armstrong, Lord Bledisloe, Viscount Inchcape, Sir Charles C. McLeod, Sir John O. Miller, Sir George Sutton, and Sir Charles Wakefield. In their places the Council recommend Sir Edward Gait, Mr. John S. Highfield, Sir Francis G. Ogilvie (none of whom have served on the Council in any capacity during the current year), Mr. Llewelyn B. Atkinson, Sir Frank Baines, Mr. P. M. Evans, and Sir Philip Magnus.

The Ordinary Members of Council retiring under the regulations are : Mr. Llewelyn B. Atkinson, Sir Frank Baines, Sir William J. Pope and Sir Richard Redmayne. In their places the Council recommend Sir Atul C. Chatterjee, Sir Edward Davson, Sir John Dewrance, and Sir Henry Miers, none of whom have served on the Council in any capacity during the current year.

The Council also recommend the appointment of Sir Charles H. Armstrong and Sir George Sutton as Treasurers in place of Mr. P. M. Evans and Sir Philip Magnus who are recommended for election as Vice-Presidents.

XV.—OBITUARY.

The Society has lost some distinguished Fellows during the year, but the number is fortunately smaller than usual.

Lord Kenyon had been a member for nearly forty years.

Sir John Benton was exceedingly well known in the annals of irrigational engineering in India.

Sir William Galloway was regarded as one of our highest authorities on colliery explosions.

Lieut.-Colonel Allan J. C. Cunningham was for many years a most regular attendant at the Society's meetings, and very frequently took part in the discussions.

Mr. Leon Gaster was the pioneer of the science of illuminating engineering and devoted his whole life to promoting the study of the subject.

Mr. Charles Simpson Bentley was elected a member of the Society forty-six years ago.

Obituary notices of these and some other Fellows have appeared in the columns of the *Journal*.

XVI.—FINANCE.

The Financial Statement for 1927, published in accordance with Section 25 of the Society's Bye-Laws in the *Journal* of June 22nd, shows that the excess of expenditure over income for the year was £570 5s. 8d. This was accounted for by the fact that about £500 had been spent on printing machinery, £130 on re-leading the roof, and £60 on the lighting of the hall and staircase. These items are all of the nature of capital expenditure, and are not likely to recur for a considerable time.

At the end of 1921 an appeal was made to Fellows of the Society for £50,000, the amount required to purchase and re-decorate the Society's House, which although specially built for the Society by the Brothers Adam in the year 1772, had never belonged to it. Of the £50,000 required, £43,401 14s. 5d. has been subscribed, leaving a balance outstanding of £6,598 5s. 7d. This is now represented by an overdraft at the bank on which the Society has to pay interest charges. By the end of this year a period of seven years will have elapsed since the appeal was first issued, and it would be a most welcome relief to the Society's finances if the completion of the seven years period could also mark the attainment of the round figure of £50,000.

XVII.—PENSION SCHEME.

The Council have felt for some time that, in order to bring the Society into line with other great scientific and learned societies, it was desirable to institute a pension scheme for the benefit of the staff. At the beginning of the present year such a scheme was inaugurated. Endowment assurance policies were taken out for most of the members of the staff, five per cent. of their salaries being deducted for this purpose, and a contribution of ten per cent. being added by the Council. In the case of five senior members of the staff, whose ages made it inadvisable to adopt this system, provision is being made in another way. The staff have expressed their high appreciation of the advantages which they will derive from these arrangements.

THE CHAIRMAN, in moving the adoption of the Report, said that the useful work which the Society had been doing during the past year had been in no way inferior to the work accomplished in the one hundred and seventy-three previous years of its existence. He was very glad to announce that the Mitchell Trustees had been able to offer to the Society, for competition in connection with the Society's examinations, a Travelling Scholarship of about £120, for the best student in Spanish.

SIR THOMAS H. HOLLAND, K.C.S.I., K.C.I.E., D.Sc., F.R.S., in seconding the adoption of the Report, said he was sure the Society would like him to congratulate the Chairman on having got through his year of office so successfully.

During the year the number of entries for the Examinations had reached and passed the previously large record, the figure now being over 100,000. Another feature of the year was the satisfactory progress of the Competition of Industrial Designs. For the first two or three years the Society had been in some doubt whether the competition would establish itself on a firm footing, but this year they had an increase of something like 50% in the number of designs sent in, showing that throughout the Country the Competition was forming a good supplement to the Commercial Examinations. He would also like to draw attention to the careful preparation of the Annual Report, the summaries of the papers being, as usual, extremely good, and very valuable to members who were not able to attend all the meetings.

The Report was unanimously adopted.

The new List of Council, having been suspended in the Library in accordance with the new Bye-Laws, and no additional nominations having been made, the CHAIRMAN declared that the following were elected to fill the several offices. (The names in italics are those Fellows who have not, during the past year, filled the office to which they have been elected) :—

PRESIDENT.

H.R.H. The Duke of Connaught and Strathearn, K.G.

VICE-PRESIDENTS.

*Lord Askwith, K.C.B., K.C., D.C.L.

Llewelyn B. Atkinson, M.I.E.E.

Sir Frank Baines, K.C.V.O., C.B.E.

Sir Charles Stuart Bayley, G.C.I.E., K.C.S.I.

Sir John Cadman, K.C.M.G., D.Sc.

*Sir Dugald Clerk, K.B.E., D.Sc., F.R.S.

Sir William Henry Davison, K.B.E., D.L., M.P.

Peter MacIntyre Evans, M.A., LL.D.

Sir Edward Gait, K.C.S.I., C.I.E.

Sir Alexander Gibb, G.B.E., C.B.

Sir Robert Abbott Hadfield, Bt., D.Sc., F.R.S.

Rear-Admiral James de Courcy Hamilton, M.V.O.

John S. Highfield, M.Inst.C.E., M.I.E.E.

Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S.

Sir Herbert Jackson, K.B.E., F.R.S.

Major Sir Humphrey Leggett, D.S.O., R.E.

Sir Philip Magnus, Bt.

Sir Francis G. Ogilvie, C.B., LL.D.

Hon. Sir Charles A. Parsons, O.M., K.C.B., LL.D., D.Sc., F.R.S.

*Alan A. Campbell Swinton, F.R.S.

Professor John Millar Thomson, F.R.S.

Sir Frank Warner, K.B.E.

*Sir Henry Trueman Wood, M.A.

Sir Alfred Yarrow, Bt., F.R.S.

ORDINARY MEMBERS OF COUNCIL.

Rt. Hon. George N. Barnes, C.H.

Sir Atul C. Chatterjee, C.I.E.

Captain Sir Arthur Clarke, K.B.E.

Sir Edward Davson, Bt.

Sir John Dewrance, K.B.E.

Col. Sir Arthur Holbrook, K.B.E., M.P.

Sir Reginald A. Mant, K.C.I.E., C.S.I.

Sir Henry A. Miers, F.R.S.

Col. The Master of Sempill.

James Swinburne, F.R.S.

Carmichael Thomas.

Lt.-Col. Sir Arnold T. Wilson, K.C.I.E., C.S.I., C.M.G., D.S.O.

TREASURERS.

Sir Charles H. Armstrong.

Sir George Sutton, Bt.

THE CHAIRMAN then proposed a cordial vote of thanks to Mr. G. K. Menzies (the Secretary), Mr. W. Perry (the Assistant-Secretary and Secretary of the Indian and Dominions and Colonies Sections), Mr. J. H. Buchanan (the Accountant and Examinations Officer), Mr. C. D. Cassidy (the Librarian), Mr. H. J. Dack (the Chief Clerk), and to the other officers of the Society, for their services during the year.

MR. A. A. CAMPBELL SWINTON, F.R.S., in seconding the motion, said that he thought all the members of the Council were very well aware of the very great amount of work that the Secretary, the Assistant-Secretary and the other members of the staff had to do, and how very well they carried it out. He thought there was no more to be said—it was so self-evident.

The vote of thanks was carried unanimously.

LORD ASKWITH, in proposing a vote of thanks to the Chairman, said that it was with unusual feeling that the meeting would pass a vote of thanks to Sir Philip Magnus for taking the Chair that afternoon, and for his work during the past year. This was the last day, he understood, that he held office. It had been a remarkably full year, and culminated very happily in the offer of a Travelling Scholarship by the Mitchell Trustees, which the Chairman had just announced. He was sure the meeting would wish Sir Philip Magnus many more happy and pleasant years.

The motion having been duly seconded, the vote of thanks was carried unanimously.

THE CHAIRMAN, in acknowledging the vote of thanks, said that his relations with the Society during the past year had been practically in all respects most agreeable to him and most satisfactory in their results. It gave great pleasure to him to preside over the Annual General Meeting in the year when for the first

time a Parliamentary Committee had had the Society's work under consideration. He had had the opportunity of giving some evidence before the Committee, and he hoped that the Report would put on record the great services in the matter of education the Society had given to the industries of the country. He recalled that in the year 1854, only one candidate presented himself for examination, and that for over three-quarters of a century the work of the Examinations had not gone back but had enormously increased.

NOTES ON BOOKS.

ALFRED YARROW: HIS LIFE AND WORK. Compiled by Lady Yarrow. Popular Edition. London: Edward Arnold & Co. 5s.

We are exceedingly glad to see this popular edition of the life of Sir Alfred Yarrow. It tells a wonderful story of brilliant success won after a youth of strenuous struggle and some disappointments.

Alfred Yarrow was a born inventor. At the age of eight he devised an automatic wool-winder to save him from the boredom of holding skeins whilst an elderly aunt wound the wool into balls; and a few years later, he devised a self-acting candle extinguisher so that he should not be interrupted at his work to go and blow out the candle of the same lady after she had retired to bed. While still a boy at school he devised an electric telegraph by which he was enabled to maintain communication with a school friend, at a total cost of half-a-crown.

Among the most important of his early inventions was a steam carriage, built by himself and his friend, Hilditch, which was shown at the International Exhibition of 1862, and attracted a great deal of attention. In a way, it was too successful, for rushing along a road at night at 25 miles an hour, it frightened a policeman's horse, and the policeman's leg was broken. This, among other causes, led to the passing of the famous "red-flag" law, which put a full stop to the development of the motor-car for many years. A delightful photograph is printed in the book, showing five gentlemen taking the air in the steam carriage, arrayed in top hats, while the mechanic sits beside the boiler in a bowler.

The name of Yarrow will, of course, be always closely associated with ships. Lady Yarrow gives an extremely interesting account of the starting of the firm, "Yarrow and Hedley, Engineers," in the Isle of Dogs. The first steps were terribly difficult, and two years' incessant work was only rewarded with a loss; but at this time Yarrow built his first steam-launch, and thenceforward his progress, if still for some years slow and arduous, was assured. Among the earlier boats that he built were the *Ilala*, the first steamer launched upon Lake Nyassa, and the *Adventure*, which was constructed for the British Government to put down slavery on the lake.

Early in the present century, Yarrow's works were moved from the Thames to the Clyde, and many fine torpedo-boats and other craft were built in the Scotstoun yards. Yarrow's inventiveness was constantly being called to his country's aid during the Great War. Lord Fisher had an immense opinion of his genius and, whenever a new kind of craft had to be devised to meet some new emergency, it was to Yarrow that he turned. Thus, gunboats of one description were wanted for the Danube, while gunboats of quite another type were wanted for the Tigris. The latter were used with extraordinary effect and may be said to have decided the fate of Bagdad and the success of the Mesopotamian campaign.

Lady Yarrow's book gives a fascinating account of a long and remarkable career, and it should have a special interest for Fellows of the Society, who have elected Sir Alfred Yarrow one of their Vice-Presidents.

THOMAS CHIPPENDALE. By Edwin J. Layton. London: John Murray. 10s. 6d. net.

Among distinguished past members of the Royal Society of Arts was Thomas Chippendale the Second, the most renowned of the three Thomas Chippendales. Mr. Layton has done valuable work in thus reviewing his life and origin. For Chippendale occupies a very special place in the history of furniture making: he was not merely an outstanding—or *the* outstanding figure—in his generation, but a man who gave to experts in his art a new status among creative artists of all sorts.

Difficulties as to his life and origin must be attributed precisely to the comparatively low esteem in which cabinet makers were held until he wrought the change; also, "it will be remembered that for the greater part of the eighteenth century architects designed, not only the house and fittings, but the furniture also." Normally Chippendale would have been regarded as merely one of the many skilful craftsmen of the period."

He left no room for doubt that he was more than that. His book, "The Gentleman and Cabinet-Maker's Director," was by itself an achievement; though very expensive, it soon ran into three editions, and Sheraton, writing forty years later, took more than one leaf out of his great rival's work. And if the architects of the eighteenth century knew something about designing furniture, Chippendale knew something about architecture.

The theory which Mr. Layton rejects is that Chippendale was the son not of Thomas Chippendale the First, who had a reputation as cabinet-maker in the reign of George I, but of a John Chippendale who was a joiner in a remote Yorkshire village. For instance, the famous chair in the Soane Museum is denied by some to be the work of Thomas Chippendale the Second, though Sir John Soane knew Thomas Chippendale the Third, and what is more, can be proved to have employed the firm of Chippendale and Haig. From the middle of the century the great man was producing works of an order which gave him his reputation, and Mr. Layton calls on the sceptics to name an alternative maker for the celebrated chair. Besides, "if we may judge by every-day experience and by what has happened in all parts of the world since history was written, we conclude that Chippendale had a father of great ability who inspired the child and boy by his own work. . ."

A practical and pertinent consideration is this: where would the son of an obscure Yorkshire joiner have got the leisure and money to enable him to set about compiling a huge book like the "Director?" That he had a workshop of importance is shown by an entry in the *Gentleman's Magazine* of April 5, 1755, which states that "a fire broke out in the workshop of Mr. Chippendale, a cabinet-maker near St. Martin's Lane, which consumed the same wherein were the Chests of 22 workmen."

The discovery of a Deed at Wakefield by Colonel Chippendale has been the main cause of the dispute as to Chippendale's parentage, but the conclusions to be drawn from such evidence as this document affords are simply that Thomas Chippendale was helping certain relatives in Yorkshire by money and guarantee; not that he was the son of John Chippendale.

At the beginning of his book Mr. Layton has arranged a careful chronology of all the known facts of Chippendale's life. Where suppositions have provisionally to be relied on Mr. Layton's seem preferable to the others.

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*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C.(2.)*

NOTICE.

ART CONGRESS STUDENTSHIP.

In the year 1888 an Association was formed under the title of "The National Association for the Advancement of Art and its Application to Industry," for the purpose of holding an Annual Congress in different parts of the country for the reading of papers on the application of Art to Industry and the discussion of questions of a practical nature connected with the furtherance of the interests of Art. In the year 1906 it was resolved to wind up the Association, and to devote its then existing funds to the foundation of an open Studentship for the promotion and encouragement of Art, to be awarded from time to time by Trustees, the Trustees then appointed being Sir William Cuthbert Quilter, Bt., who had been Treasurer of the Association, Mr. (now Sir) Reginald Blomfield, and Mr. Whitworth Wallis.

The Trustees recently approached the Royal Society of Arts with a view to the Trusteeship being taken over by the Society. The Council of the Society agreed to the proposal, but as it was necessary under the terms of the Trust that the Trustees should be three in number as hitherto, the trusteeship has been vested in the Royal Society of Arts, Sir Frank Warner, K.B.E., a Vice-President of the Society, and Mr. Carmichael Thomas, a Member of the Council.

It was thought that the Studentship would be appropriately associated with the Society's Annual Competition of Industrial Designs, and an Art Congress Studentship of the value of £50 has accordingly been offered in connection with the Industrial Designs Competition of 1928. The Studentship may be awarded to any candidate in any Section of the Competition, whether a prize-winner or not, whose work suggests that he or she is in a position to profit by the Studentship, which must be expended in the furtherance of his or her work in a manner approved by the Council of the Society.

PROCEEDINGS OF THE SOCIETY.

TWENTY-SECOND ORDINARY MEETING.

WEDNESDAY, MAY 16, 1928.

ALAN A. CAMPBELL SWINTON, ESQ., F.R.S., Vice-President of the Society,
in the Chair.

THE CHAIRMAN said that the lecturer that evening, Mr. W. Worby Beaumont, required no introduction. He was one of our oldest automobilists, and some years ago wrote a very important work on the history and mechanics of automobile design and construction. Ever since its inception Mr. Worby Beaumont had, he believed, been the consulting engineer of the Automobile Club, and for many years he was consulting engineer to the Metropolitan Police in connection with all matters relating to motor propelled vehicles of all kinds. There was, therefore, no necessity for him to make any further remarks, and he had much pleasure in calling on Mr. Worby Beaumont to read his paper.

The following paper was then read : —

MODERN MOTOR CAR DESIGN.

SOME CRITICISMS AND SOME SUGGESTIONS.

By W. WORBY BEAUMONT, M.I.C.E.

The acceptance by the Royal Society of Arts of this short paper is a confirmation of the honour bestowed upon me when, in 1895, I was invited to give the first series of Cantor lectures on Mechanical Road Vehicles, a series which with other work was, I am allowed to believe, of material aid to the efforts of others in obtaining the repeal of the energy-destroying influence of the Locomotives in Highways Act of 1861, and the decision of the Court of Queen's Bench, in 1881, which placed every kind of self-propelled vehicle under the restrictions relating to heavy traction engines.

These lectures were followed in 1896 by a paper on the then recent developments in mechanical road vehicles, and in 1903 by a further series of four Cantor lectures on the same subject.

This reference to past occasions on which I have dealt with the design, construction and working of the motor car, is made necessary because after the lapse of years it has become desirable to make some observations on the trend of modern design and construction. In those past days there was a tax on petrol, but there was no bar to the development of engines and use of power.

For some time the necessity for a standard method of assigning the dimension and power of motor car engines gave rise to much uneasiness when the previously existing tax on petrol was replaced by a tax on the horse-power of each vehicle.

It was urged that this materially affected the freedom of the designers of engines and the otherwise possible development of engine construction.

Although it would be far better, from every point of view, except, perhaps, that of the clerical departments of the Customs, if motor vehicle taxation were levied by means of a flat rate tax on petrol used by every class of vehicle, it is only to a small extent that taxation by horse power has brought about limitation of design in the English motor vehicle of to-day.

It has, on the other hand, directed ingenuity and invention so powerfully into urgently directed occupation, that we now have petrol engines of far greater power and efficiency than ever, and greater than there would have been but for this incentive. It became necessary to produce high power under the limitations of cylinder diameter imposed by the accepted rating which did not, although it might easily have introduced, the stroke factor, too. This I urged as a member of the Treasury Committee on H.P. Rating, but was in a minority.

The result has been that able and earnest men of inventive capacity, ignoring Carnot, and supposed limitations of combustion in closed cylinders, have, among other important factors, adopted the steam engineer's practice of least possible clearance spaces and free exhaust. The result is that we have the small, very high speed engines of to-day which have much to their credit, and should help in the production of the light car of good power. (There remains now the application of the same ingenuity to the development of the 2-cycle engine.)

The obverse of this, however, is the tendency to use these very high speed small dimension engines in heavy vehicles, and to make necessary the continuance of three and four speed gear boxes, and incessant speed gear change by every driver.

This is bad, for great improvement in engines should have tended to the elimination of change speed gear or the use of perhaps one change. Cars have been run under R.A.C. long distance certificated trials on top speed gear, or straight through drive, alone, but of course, the routes for this stunt were wisely chosen, and the driver was no stranger to his car. This, however, ought to become a common car capability, and for this the larger dimension, lower average speed engine is necessary, especially for cars for export to new countries, to our Dominions and Colonies.

Hence the trade-depressing handicap of our taxation by horse power. Power is the cheapest thing one can want if one has a use for it, and power obtainable by small extra dimensions in motor cars for colonial use is cheaply obtainable so far as the motor car maker is concerned, and, with certain features of chassis design, is what our Colonial would-be customers wish to buy from us, but are compelled to go to America to make their purchase.

These matters are among those calling for serious commercial consideration, but there are others of even more importance as to future construction and

trade in motor cars. It is serious, not only with regard to trade in those cars which have the light weight per horse power, wide gauge and high clearances, which are needed for much foreign trade, but for most others who produce general purpose cars.

The most important of these is the stagnation of design and the almost slavish copying of and by those English makers who are supplying the British market, and even by the foreign producers who are also enjoying its freedom. Even those astute producers, the Americans, have fallen into the trap of following a bad example.

Paucity in originality and docility in reverence of the known, mistakes in adopting for one type of vehicle that which is successful for an entirely different type and purpose, are responsible for much that is bad for the future. Standardisation has to some extent escaped from its field of utility into one of sterilising inflections. Commercial considerations as well as structural convenience make standardisation a necessity, but it may become a deterrent to originality, invention and search. Copying, imitation and other forms of reverence of the known, force into existence an unwritten code of standardising which becomes as rigid as the written, and equally opposed to departure from it into novelty on broad lines, while it encourages adoption of numerous parasitic trivialities or palliatives.

To some of these things and the admiration of similitude, the mere semblance of advance in automobile design is, perhaps, attributable.

Some time ago, in 1920, a standard was adopted for frames and body space dimensions, but it was withdrawn in 1927 as more honoured in breach than in observance, and as conflicting with all the advances in design which followed the date of its publication.

An unwritten standard has come into existence which is more intolerant in its exaction of obedience than any mathematical demonstration of an irrefutable truth. It is the result of the observance of an assured demand, fostered by makers and encouraged by the public, for cars with very low gravity centre. It has become a fetish, the faith in which has made the design and arrangement of many parts of a motor car subservient, and has introduced features of inferiority.

In designing racing cars a low centre of gravity was, and is, a necessity, in order that, among other things, safety in the necessary skidding round sharp bends at high speeds could be secured. In these cars it was a matter of little importance that the springs played small part in the comfort of the driver, and gave only vertical play in their support to the car body, a play restricted to movement vertically normal to the plane of the axis of the back axle.

With the passenger vehicle or private car there is no necessity for such provision for skidding at high speeds round hair pin bends.

On the other hand, it is desirable that the gravity centre should be sufficiently high to allow some angular sway for all that which is above the

spring shackles, and so that the stresses to which wheels, springs, and body are liable shall not be aggravatingly magnified at the wheels, by the "boxing" shocks which accompany the low angle line of incidence connecting centre of gravity and tyres at road level.

This unnecessary low centre of gravity introduces a number of defects in design and in smoothness of running.

Some of the defects may be thus summarised :-

1. It makes the cranked front axle necessary.
2. It is the cause of wheel wobble or shimmy.
3. It prevents the use of transverse springs.
4. It helps to make gravity feed difficult, thus enforcing the use of various otherwise unnecessary adjuncts.
5. It causes such a low level for the closed carriage that passengers have to stoop to enter almost as though entering through a trapdoor. Many of the modern taxicabs are superior in this respect.
6. It makes easy steering lock more difficult.

The belief in this very low gravity centre as necessary for safety is really a most illogical belief, for some of those who seem to admire it most have taken steps



FIG 1. PROOF OF LOW CENTRE OF GRAVITY.

to condemn it most, as unnecessary. One maker, in his pride in his low centre, has constructed a light frame or gantry on one of his cars carrying a man seated about twenty feet above the ground, or approaching eighteen feet above its centre of gravity. This car (Fig. 1) is said to have done a lap of the Indianapolis track at high speed with the man on top of the gantry and a complement of passengers inside, and in this trim to have "negotiated a series of artificial bumps, the very small movement of the passengers emphasising the stability of the chassis owing to its very low centre of gravity."

Taking this test, therefore, if indicative of anything, it is clear that the very low centre of gravity of the chassis is not a necessary feature of the design. This low gravity centre car would, no doubt, behave, under the provocation that causes a car to swerve at high speed and run over a kerb or on a bank and overturn, just as other low centre cars and tramcars do.

Much has been written on this subject in the motor car press, all dealing with wheel wobble and shimmy as of mysterious origin and variable in its emanations. Some have found it more severe with a hard tyre than with a low-pressure tyre, and no doubt some alleviations could arise from the use of a rather low pressure tyre, as the severity of road wheel shock would thus be lessened. Others have recommended stiff adjustment of the steering heads, or canting the springs with a wedge between spring and axle pad. All agree that it is a modern defect and go on guessing the cause.

Two papers upon wheel wobble and shimmy have been contributed to the Institution of Automobile Engineers. The importance of the subject justifies some quotations from them. Both papers testify to the comparatively recent origin of the trouble. The first of these *papers was published in 1925, and in it the author says :

"The most remarkable part about front wheel wobble is that while countless theories and remedies have been published, no full and accurate account of what constitutes wheel wobble has appeared. It is usual to differentiate between two forms of wobble, and these forms are called low speed wobble and high speed wobble. That there are two distinct forms needs no proof to those who have experienced them, and there are other points of difference besides the speeds at which they occur. The low speed wobble occurs at speeds of twenty to thirty miles per hour, and consists of a pure and simple steering oscillation. The wheels do not rise and fall appreciably, and the front end of the car is set into violent lateral vibration. The steering is also affected, and the result is most uncomfortable. . . . High speed wobble affects new cars in which every mechanical part is in perfect order. In analysing the subject we try to find what kind of front axle design is susceptible to a wobble and what kind is likely to increase and to maintain a wobble which has been started. The precise road irregularities, or speed or wheelbase, or tyre bias which start a wobble are relatively insignificant, for with an axle design which is insusceptible to a wobble or to maintain a wobble, it cannot be produced by these accidental circumstances, for all these should be allowed for in the design. We have seen that the wobble is inseparably bound up with the criss-cross vibration of the axle, and we are in a position to study

* "Front Wheel Wobble," by A. Healey.

the various factors which tend to produce vibrations of this type. Some axles are practically straight from wheel to wheel and at the same distance from the ground, while others are dropped more or less in the centre to keep the chassis low down, and the dropped axle should improve matters. However, wobble has occurred even with a front axle with a very large drop, and this characteristic is not therefore a cure."

Having got thus far partly on the track of the cause of wobble, or shimmy, as it is more often now called, the author of the paper quoted goes on to quote the experiments of others. One of these was the vertical replacement of the front springs by wood blocks "which completely eliminated the wobble," and from this the experimenter, Mr. J. E. Hale, deduced that it would be a good thing to employ stiffer springs, "but for obvious reasons this is not practicable." The writer of the paper goes on to say :-

"The experiment does prove, however, the author's argument that the criss-cross vibrations of the axle are a necessary concomitant of the wobble. . . . A further experiment by Mr. Hale was the replacement of the steering links by a hydraulic system. This entirely eliminated the high speed wobble, and Mr. Hale deduces that the wobble was caused by the interaction of the links previously referred to. This is not necessarily so, for the hydraulic gear would exert great damping influence on the wobble."

Having referred to the effect of the numerical periods of vibration of many things of a car and the periodical cycles of recurrence, the search for the basic cause of wobble is given up.

More recently, in March last, a further paper on "Automobile Steering Gear Problems and Mechanism," was read by Dr. F. W. Lanchester. This as would be expected is a very interesting paper. Having referred to the disagreeable vibration of the steering tiller of cars of about 1903, he mentions that this has no resemblance to shimmy, which has given automobile manufacturers so much trouble of late years. "The cure in the case of the old Lanchester car was easily found, the tiller was made with a solid lead casting weighing some five or six pounds. . . . nine-tenths of the forces involved were borne by the lead mass." This was, of course, a brute force method of allaying the severity of the jerks and vibrations transmitted from the Ackerman axles to the hand on the steering lever. Recently the author, Dr. Lanchester, has revived this practice in the form of a cast-iron hand wheel, celluloid coated.

Dr. Lanchester mentions the difference between the car of to-day and the automobile of some eight or ten years ago, "when these troubles were unknown," as dating a few years later than the termination of hostilities in the war. After defining high speed shimmy and low speed shimmy he mentions the caprice of its occurrence, and writes that "he met with a car which with 'four up,' would drop into a shimmy on but little provocation at about sixteen miles per hour—a low speed shimmy—and the shimmy would be maintained up to thirty miles per hour with sufficient violence at its worst

to make driving quite unpleasant ; with ' two up ' the same car, the same day, nothing changed, could be driven right through its shimmy period, over and over again, without dropping into a shimmy, but would occasionally do so, but with ' one up ' nothing would induce the car to go into a shimmy at all." It is to be regretted that Dr. Lanchester did not pursue this experiment, until with his usual acumen, he had detected and interpreted the origin of the caprice he described.

After stating five conditions which any theory put forward to account for the phenomenon must meet, Dr. Lanchester gives five differences between the cars of, say, eight years ago and now, upon which the finger may be placed, and six factors which may play a contributory role, one of which, " elasticity of front-axle mounting," is certainly important, but he does not mention the one most notable and pregnant difference between the cars of eight years ago and now, namely, the dropped axle cranked outside the springs and between them and the stub axle, necessitated by a low centre of gravity.

As in the paper first mentioned no explanation of the general cause of the modern car shimmy is found or given. In fact, it is given up and resort is made to methods of forcible suppression.

Dr. Lanchester's paper ends with " the problem of damping," and a description of the Lanchester damper. He says :—

" Whilst there are various palliatives by which the troubles connected with steering may be ameliorated, the most effective, in fact, the only effective method of killing trouble, is by damping, unless recourse is made to a complete revision of the accepted design and present system of wheel and axle. But the problem is not an ordinary one ; the conditions under which the damper is required to function require special study, and the damper itself is a highly specialised piece of mechanism."

The damper described by Dr. Lanchester is, as one would expect, a most ingenious piece of mechanism, but it may be questioned whether it does not rather capitulate to the disease than eradicate it.

We are not told why it was that " eight or ten years ago these troubles were unknown," and we are not told why it was that the car that shimmied so severely with four or five up could not be induced to shimmy with one up. We are told that we must have recourse to a damper, or a " complete revision of the accepted design and present system of wheel and axle."

This last is the one true alternative, for inertia of motion and of rest are both good servants but very bad masters.

Taking, then, the defects I enumerated in the foregoing—

(1) the cranked axle. Fig. 2 is a sketch drawing generally illustrative of the common cranked axle, the distance $a-b$ and $b-c$, being the factors of greatest mechanical importance in the origin of shimmy. Figs. 3, 4, 5 and 6 are of four of the many front axles which have been illustrated from photographs or sketches in the *Auto*, as those of prominent makers of cars. Fig. (3) to (6) show a few of the many modern cranked front axles. It

will be seen that in all of them the centre of the wheel is considerably above the level of the axle pad on which the springs are fixed or pivoted. This places the axle in the position and action of a winch handle, the road wheel turning on the pivoted axle, just as a ferrule handle turns on a winch handle, the axle, though pivoted, being virtually integral with the cranked axle through the action of the steering gear.

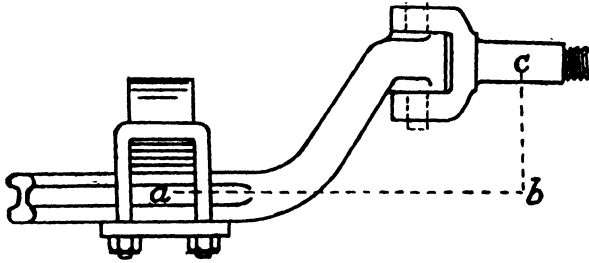


FIG 2.

The car body is, in fact, from a mechanical point of view, slung from a pendulum, the pivot of which, the upper end, is resident in the stub axle in the wheel. This pendulum length varies with different makes of car from about three inches to as much as six inches. As a pendulum its natural period of oscillation cannot be appealed to as an originating or maintaining cause of shimmy or wobble, but as a mechanical link between an unresisting pivoted point at one end and an attachment to a spring at the other end, it has a powerful mechanical advantage in causing elastic flexure in the spring in the direction of its length and in causing in it a torsional twisting elastic flexure of high period, producing what Mr. Healey probably means by criss-cross vibrations of the axle. Hence the angular effort expended on the stump steering axle and the elastic flexure quarrel, and ambiguous stresses set up there and at the steering wheel, following

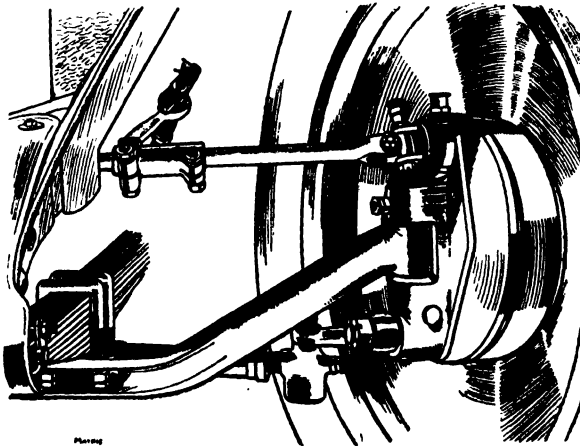


FIG 3. A LONG DEEP CRANKED AXLE.

every impulse and road resistance variation felt by and transmitted by the road, with the consequent vibration at variance with the plane of the wheel.

Every obstruction and every variation in road resistance met with by the road wheel on the ground is thus transmitted through the crank arm of the axle to the attachment of the spring with a turning movement proportional to the crank arm dip of the axle. Rotative motion of the crank arm is resisted by the attachment of the spring. The spring has to resist the turning effort not only by contrary elastic flexure of the front and rear half of the spring,

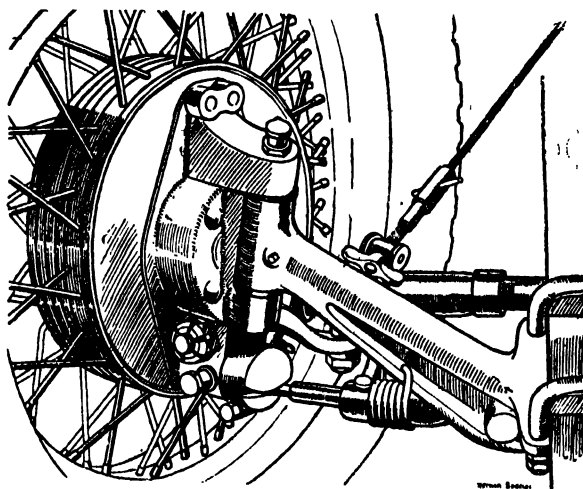


FIG 4. EXTREME CRANKED AXLE.

but by transverse bend or twist-resisting effort, the axle crank being exposed to twisting stress and a rearward bending stress. The wheel on its axle, and with the axle, is thus angularly and momentarily displaced from its rectilinear

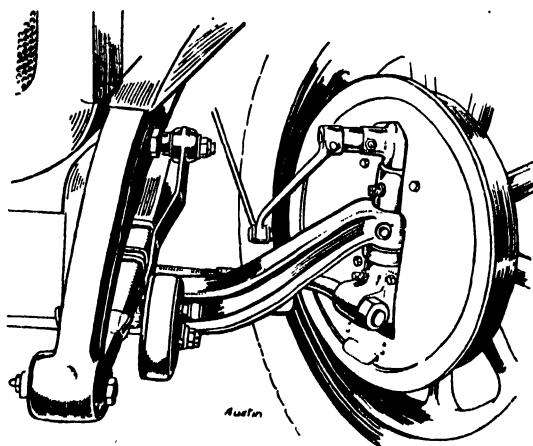


FIG 5. AN ENGLISH CRANKED AXLE.

advance only to be brought back to it by the elastic effort of the spring. The repetition of this action, and the spring recoil, give to the wheel that evidence of vibratory spring effort which results in what is called wobble or shimmy.

It will thus be seen that the greater the crank dip or difference between the height of the spring clipped part of the axle and that of the axle on which the wheel runs, and the greater the distance from spring clip to wheel centre, the greater the stresses on the crank axle and on the springs. An atmospheric bearing for a steering wheel is a poor support, and long cantilever from spring clip to king pin is bad.

The wheel shimmy is thus the accompaniment of modern car design. It was never remarkable in cars of a dozen years ago, and it has not been extinguished in any degree by the palliatives which have recently been tried or suggested.

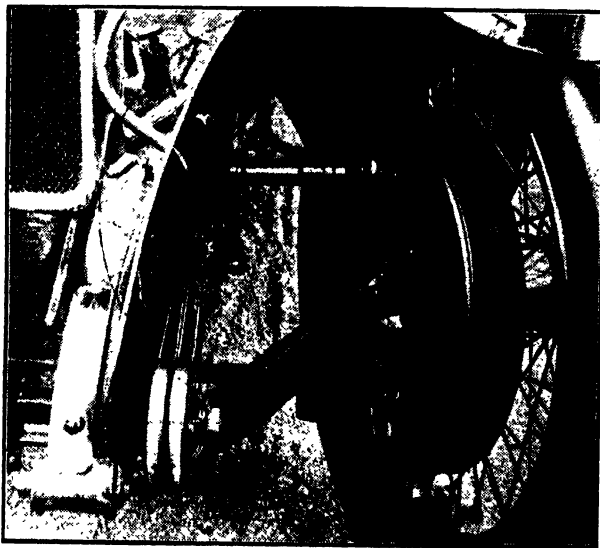


FIG 6. A FRENCH CRANKED AXLE.

One of the palliatives should be mentioned; it is the insertion of a tapered wood wedge between the spring and the spring pad on the axle. With sufficient taper this will, of course, modify the range of wobble of the wheel, because it throws the upper part of the crank arm backwards, tilts it from the vertical $A B$ (Fig. 7) to the line $a b$ and the line of impulse of stress from tyre at C to axle at b . This slightly reduces the turning effort on the axle and the contrary flexure bending of the spring, and therefore the rebound acting at an angle with the plane of the wheel. It does, however, throw a permanent twisting stress on the dip arm of the crank, due to weight and running stresses.

Another palliative is that of reducing the freedom of the turning of the stub

axle on the king pin and an appliance for this purpose is actually an article sold as an accessory. It is however as barbarous as it is unmechanical.

Other means of reducing wobble action have been proposed and some tried, but the mechanical origin of the action has not been ascertained. Damping the wobble by forms of restraint of the steering mechanism other than those mentioned have been proposed, as hereinbefore mentioned.

From what I have herein said, however, it will be seen that no accessory damper is required if the stub axle and the main axle have approximately the same centre line. By thus modifying the main axle with due reference to mechanical fitness, wheel wobble will cease, and to a large extent the gyroscopic effects, except so far as they arise from defects in balance of wheel and wheel and tyre fittings.

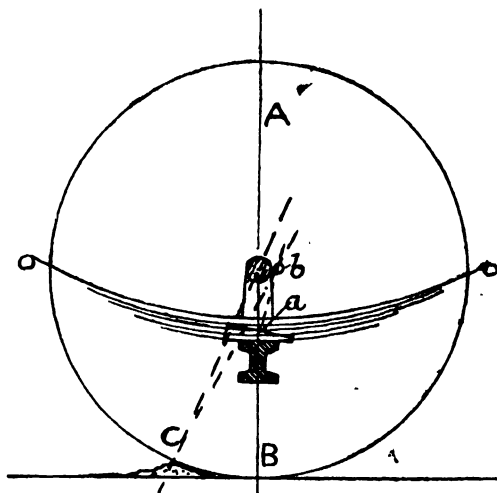


FIG 7.

Turning now to the third defect introduced by the low centre of gravity and cranked axle, or made less easy of employment, namely, the use of transverse springs. There can be no doubt that easier riding can be obtained by suitably designed and properly mounted cross springs, although their use may entail the necessity for some form of reach or stretcher bars.

One cause of the easy riding with these springs is the fact that both halves of the spring usefully come into play when only one of the two wheels run over an inequality in the road. The half next the wheel which meets an obstruction flexes upward while the other half receives a contrary flexure, but of less magnitude. With the common arrangements of semi-elliptic and other springs, relief depends on the flexure of the spring next the wheel which meets the obstruction.

With transverse springs, however, shimmy would occur if the centres of the wheel and of the axle do not coincide or approximately so. If the cranked

axle were used with a cross spring, the stretcher bars would have the pivot near the top of the crank of the axle, but, of course, the cranked axle would still act prejudicially on the spring, and it is an unnecessary defect.

In conclusion, mention may be made of some other parts of the modern car to which exception may be taken.

In many cars unnecessarily expensive torque and propeller shaft arrangements are adopted, many of them adding quite unnecessary weight and inaccessibility.

Front wheel brakes of quite unnecessary size and weight are used, adding very much to the wheel wobble stresses thrown on the springs. Some of these add as much weight as would be incurred if a front wheel drive were used, making front wheel brakes less necessary.

Maker after maker has introduced some detail or another as an apparent improvement, then other makers have adopted whatever idea there may be in this detail modification, and has added something more, without introducing any real advance in the service-giving mechanical road vehicle.

DISCUSSION.

COL. THOMAS M. HUTCHINSON, D.S.O., O.B.E., M.I.A.E., M.I. Mech. E. (Mechanical Transport Adviser, India Office), said he had only seen the paper as he entered the meeting that night, so he could only give a few ideas which had occurred to him while Mr. Beaumont was reading the paper. In the first place he wished to draw attention to the fact that while Mr. Beaumont stated that only to a small extent had taxation by horse power brought about limitation of design in the English motor vehicle of to-day, later on he spoke of the trade-depressing handicap of our taxation on the horse-power basis. He (the speaker) had had a certain amount of experience abroad and had seen something of the competition between English-made motor cars and lorries and foreign makes, and his impression generally was that the small power engine of high efficiency had been at a distinct handicap under colonial conditions in competition with the high power and lower efficiency of the American or other engine. This affected the question of maintenance; when the high efficiency engine had fallen off a little from its original condition they found it seriously handicapped when compared with the lower efficiency engine. The general impression he had was that in this country we had suffered from the handicap of the taxation formula.

With reference to "shimmy," a good many years ago—about 1902 or 1903—he had a car which had distinct periods during which bad shimmy used to be set up, so that so far as he was concerned the shimmy was not quite such a modern thing as perhaps had been suggested. Incidentally, he happened to know another car which produced a shimmy effect and had a straight axle. He was not quite clear that the causes of shimmy were altogether due to the cranked axle alone. It was probable that the cranked axle had largely contributed to shimmy, but he wanted to point out that it was not the sole and only cause. Generally speaking, the effect of putting a wedge into the axle was the most effective way of dealing with shimmy, but it did not do away with the effect in all cases. He had often found that the use of a wedge had distinctly altered the period of shimmy and had been a means, for practical purposes, of getting over the difficulty.

MR. H. R. RICARDO said he felt rather diffident in taking any part in the discussion because Mr. Worby Beaumont's paper dealt very little with engines, and engines were the only part of the motor vehicle that he felt really competent to discuss. He heartily agreed with certain remarks of the lecturer with regard to copying and imitation. He had seen and watched a good deal of this, and in almost every instance it had ended in disastrous failure. He did not think there was any difficulty in appreciating why it should end in failure. It did not take any great knowledge of human nature to show that copying with its lack of appreciation of circumstances must usually fail. Mr. Worby Beaumont spoke of "paucity in originality and docility in reverence of the known." That was true of the active management of a very large proportion of our firms, but it was untrue of the technical experts in those firms. He had seen a good deal of the work of many British motor-car companies, and he had been struck by the great ability of the technical designers. He had also been struck by the lack of appreciation of them in this country, whereas abroad the active management of a firm was generally in the hands of a man of technical knowledge and judgment. Continental firms usually discussed their problems on their technical merits, but with an English firm the question immediately asked was, "who else does it?" That summed up very largely the difference in attitude. He might perhaps relate an experience which he had quite recently. He was called in by a large firm of English manufacturers to discuss a new design. They had decided to produce a new engine. He was shown into the Board room, and on the table was a very large number of exhibits in engine parts. The Managing Director commenced with a short speech, explaining that the time had come to produce an entirely new design, but before doing so he had circularised all the firm's agents and sales managers to find out the best parts of the best cars—the new design was to embody the best feature of all the best engines—and the material on the table represented those best features. It was palpable that none of those parts could be mated together. The firm's own designer was present at that meeting, but he was not consulted. Afterwards he showed him (Mr. Ricardo) that he had designed an admirable engine in every way, but rather than accept the advice and design of their own talent they preferred to call in outside aid, and the design was to be dictated by a committee of salesmen and all the collection of misfits was thrust on to the unfortunate designer to put together as best he could. That was an illustration of the attitude which prevailed in quite a number of British motor-car firms.

MR. A. E. PARNACOTT congratulated Mr. Worby Beaumont on putting such a valuable paper before the meeting and said he proposed to discuss the vehicular part of the subject of motor-cars in its bearing on the matters dealt with by Mr. Beaumont. He would like to say, however, in reference to gear change—in respect of which Mr. Beaumont had suggested that engines should be larger or that there should be less gear change—that the speeds of the engines had been increased in recent years and that engines now accomplished 5,000 revolutions as compared with 3,000 revolutions, which was considered high at one time. This had the effect of causing more drive on the closed throttle, and a larger fuel consumption. If they controlled the engine speeds by increasing the gear ratio rather than by throttling they would get far more miles per gallon, and he was quite sure that the careful selection of gears for vehicles could easily increase the miles per gallon by something like twenty per cent. by means of alterations in the gear-box alone. He had one or two illustrations to help the meeting understand clearly the matters which he desired to put before them. He did not believe that the cranked front

Royal Society for the Encouragement of Arts, Manufactures and Commerce.

JOHN STREET, ADELPHI, LONDON, W.C.2.

Founded in 1754.

Incorporated by Royal Charter in 1847.

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Proceedings of the Society.

THE SOCIETY was founded in 1754, and incorporated by Royal Charter in 1847, for "The Encouragement of the Arts, Manufactures and Commerce." In 1908 the Society was granted the privilege of adding "Royal" to its title.

FELLOWSHIP.—At the Annual General Meeting held on June 24, 1914, a By-law was made authorizing all Members of the Society to use the designation of Fellow. The official abbreviation is F.R.S.A.

ORDINARY MEETINGS.—Meetings are held every Wednesday during the Session, at which papers on subjects relating to inventions, improvements, discoveries, and other matters connected with Arts, Manufactures, and Commerce are read and discussed. Courses of Lectures are delivered on other evenings.

INDIAN SECTION.—This Section was established in 1869, for the discussion of subjects connected with our Indian Empire. Six or more Meetings are held during the Session.

DOMINIONS AND COLONIES SECTION.—This Section was formed in 1874 under the title of the African Section. It has been enlarged to include the consideration of subjects connected with the Dominions and Colonies. Four or more Meetings are held during the Session.

ADMISSION TO MEETINGS.—Fellows have the right of attending the Meetings and Lectures. They require no tickets, but are admitted on signing their names. Every Fellow can admit two friends to the Ordinary and Sectional Meetings, and to the Cantor and other Lectures. Books of tickets for the purpose are supplied, but admission can also be obtained on the personal introduction of a Fellow. For the Juvenile Lectures special tickets are issued.

JOURNAL OF THE ROYAL SOCIETY OF ARTS.—The Journal, which is sent free to Fellows, is published weekly, and contains full Reports of all the Society's Proceedings, as well as a variety of information connected with Arts, Manufactures, and Commerce.

LIBRARY AND READING ROOM.—The Library and Reading Room are open to Fellows, who are also entitled to borrow books.

ELECTION OF FELLOWS.—Candidates are proposed by Three Fellows, one of whom, at least, must sign on personal knowledge; or are nominated by the Council.

The Annual Subscription is Three Guineas, payable in advance, and dates from the quarter-day preceding election; or a Life Subscription of Thirty Guineas may be paid. There is no Entrance Fee.

axle produced the wheel wobble or shimmy. The author three or four times in the course of his paper stated that he had not had an explanation of wheel wobble. *The Autocar* had an explanation from him (Mr. Parnacott) in 1920; he thought it would be found in the issue of June 26. Mr. Beaumont further preferred a higher centre of gravity. If they had a higher centre of gravity, it was the equivalent of having wheels of larger diameter. Our wheels to-day had a much smaller diameter, otherwise they would not have the lower centre of gravity. We had preferred to sacrifice the diameter of the wheel rather than to introduce any material alteration in the chassis, generally speaking. He had there a diagram which showed that when a vehicle was passing along an uneven surface and one wheel dropped down into a pot-hole the fellow wheel rose, and it was possible even with a London motor omnibus on bad roads at times to see daylight under both tyres simultaneously. The larger the wheel, the higher the centre of gravity, and the larger the amount of lateral movement of the car tread on the road in consequence. One reason why cars to-day were more comfortable to sit in was because the centre at which the load was carried had been lowered. He did feel that the British Automobile industry had entirely neglected the design and production of vehicles suitable for the overseas markets where roads did not exist or were very rough. For instance, there were three grades of mountain which had to be climbed between Capetown and the East Coast of Africa. Motor vehicles had to go sideways up one mountain, and if there was a high centre of gravity they could imagine the effect upon the vehicle. The vehicles were generally driven by blacks who knew less than the English driver about centripetal force and the vehicles often turned over. Like Col. Hutchinson, he had had previous experience of wheel wobble, and in 1903 he loosened all the steering pivots—or the king pins, as Mr. Beaumont called them. That had the effect of stopping the wheel wobble on that particular vehicle largely because the frictional resistance was greater owing to it having bearings of a plain type and not ball bearings. Explaining how wheel wobble arose, Mr. Parnacott said that if one of the two driving wheels on the steering axle dropped into a pot-hole it immediately caused precess or tilting, and the tilting of the wheel caused that wheel to turn immediately in the direction of the pot-hole. If the wheel was forced upward, the tendency was for it to turn in the other direction, and it was quite obvious that if a wheel dropped into a pot-hole it would precess in that direction and, hitting the side and rising again, it would precess in the other direction. If the speed of this movement happened to coincide with the natural vibration it started wheel wobble which might occur for some time. The remedy was to mount the steering wheels so that they were independently sprung and one wheel could thus bob up and down without affecting the other. Another and more simple way would be to have transverse springs instead of rigid axles, thus allowing one wheel to bob up and down without affecting the other; the wheel was not then tilted in the steering sense, and there was no shimmy or wheel wobble. In 1912 he produced some vehicles having spring axles, but they were rejected by the British trade and his patents had now run out. That, however, was the solution of the difficulty.

LIEUT.-COL. ALFRED HACKING, D.S.O., M.C. (Secretary, Society of Motor Manufacturers and Traders), said that his only experience of shimmy in many hundreds of thousands of miles of driving was on one occasion when he thought it was shimmy, but actually found that his steering gear had gone altogether. The point of great interest to him, and he thought to everybody else at the present moment, was the

very difficult one of the influence of the horse power tax on design, both in the past and future. He confessed with Col. Hutchinson that he found it a little difficult to reconcile two statements made in the paper by Mr. Beaumont. On the one hand, he said that the influence of the tax had been very small, and on the other hand he referred to it as a trade-depressing handicap. It had been considered—he thought entirely erroneously—that the horse-power tax had given British manufacturers a certain protection from their foreign competitors and that conditions in that respect might have outweighed the disadvantages owing to the interference with the freedom of the designer. He thought that the claim that the horse-power tax was a protection was a factor of the past, particularly in respect of the United States, and not of the future, and he thought they would find there were few manufacturers to-day who would not prefer to be freed entirely from any artificial interference with design from the point of view of trying to obtain the type of vehicle which would not only suit our country, but also conditions in other parts of the world. It had been his privilege during the past few years to visit many countries, and it had been very depressing for a Britisher to see in countries like Australia, New Zealand and South Africa, an extraordinary preponderance of American cars, which apparently served their purpose very well. One did not necessarily say that the reason for the difficulty of the British manufacturers getting these markets was due to the horse-power tax, because they knew that the French and Italian manufacturers were also finding it difficult to get into the Dominions or any other part of the world; but it could not be disputed that if they were to get some standardisation of design suitable for our conditions and the conditions in other countries they should be freed entirely from an appalling prejudicial factor. He hoped that the lecture they had listened to that night would have some little result in persuading the powers that be that there was no factor more hampering to the successful exploitation of the British motor industry abroad than the influence of a very heavy taxation based on a purely theoretical formula.

THE MASTER OF SEMPILL said he had expected that Mr. Beaumont in his interesting paper would have said something about the gear box and indicated possible lines of improvement. Motor cars were designed, or should be, for the general public to handle and not for experts. The art of gear changing had not been acquired by the large majority of those who used cars, and would not be acquired unless this operation were rendered entirely fool proof, and in time no doubt, done away with. Mr. Beaumont would, no doubt, say that the development of a torque converter was a possibility of the not distant future. In this he would agree but some years must elapse and these must be bridged. In this connection the development of the free wheel was interesting and he would like to hear the lecturer's comments on its possibilities. He felt that the free wheel type of car would become common and eventually universal. A car so equipped was far more economical to run and more comfortable to ride in, and assuming the free wheel unit to be fitted at the rear end of the gear box, gear changing under all conditions was rendered fool proof. He would like to add his congratulations to those of previous speakers on an interesting paper by a veteran pioneer of the automobile.

MAJOR E. G. BEAUMONT O.B.E., (President, Institution of Automobile Engineers), said he would first of all like to offer a filial tribute of appreciation to Mr. Worby Beaumont for his most interesting paper and to enter a small protest against the

depreciation which had been evident that night, not only in the lecture but also by a previous speaker in regard to British manufacturers. Mr. Ricardo, while giving possibly a well-deserved trouncing to the poor procedure of certain British manufacturers, did not, on the other hand, give the credit which was due to many excellent manufacturers. After all, it was evident that they were able to produce as fine engines, and in some cases better engines, as could be produced anywhere in the world. The question of wheel wobble was a subject which had been recently treated. It was undoubtedly a matter which had aroused much controversy. He had noticed that with modern cars, capable of high speed, and where the straight axle was employed, wheel wobble was less evident, but he doubted whether that could be said of all modern cars having that construction. Incidentally, it was worth recording that when the well-known low speed wobble — the forty miles an hour wobble of pre-war days — took place, it also occurred on cars which had straight axles; and he thought that if Dr. Lanchester had been present that night he would have cited his own car as an example with which he had experienced trouble. He thought that the probable explanation was that the balancing and other factors were not so closely watched as they were to-day. Nowadays they were troubled with the sixty miles an hour wheel wobble, and there was real cause for alarm. He believed it was true that the forces at work at high speeds were extremely high. It was possible that with the stress imposed by high speed travel the form of axle referred to in the paper might be one primary originating cause of the trouble. There had been reference that night to the effect of taxation, and it had been said that the Colonial buyer seemed to prefer the big easy-working engine. He did not think that any successful argument had been brought forward that night in condemnation of the high-speed engine. It was a question of degree. High speed being carried to the fore, before design, material and construction, had enabled the necessary conditions of high speed to be realised, represented really a designer's mistake, and he thought it possible that in their pioneering work in producing the high-speed efficient engine they might have gone too fast. On the other hand, he thought all engineers would agree that if they had succeeded in making a high-speed automobile engine, they had succeeded in making a great advance in practice, and he thought that the outcome of the work engaged in for some years had led to that position. Provided that they continued to advance they would maintain their position in the markets of the world. He believed their friends in the Colonies had bought the big American car very often because it was a cheap car and a robust car; not because the engine and transmission characteristics were superior. However, it was probable that the compromise in taxation which they had now reached would have a good effect upon the trade. Colonel the Master of Sempill had referred to improvements in transmission directed towards rendering changed speed gear action more simple. He (the speaker) had had the opportunity of trying the free-wheel device both upon lorries and motor cars, and it was really surprising how far the use of such a device in transmission facilitated change. He made up his mind then that there must be a future for such a device because of secondary effects, viz., the possibility of still further reducing the size and weight of the transmission parts.

MR. WORBY BEAUMONT, in reply, said that his remarks would be brief because the arguments of those who had spoken in the discussion had, he thought, practically balanced each other, and, moreover, he was suffering from the effects of a cold and had not, unfortunately, heard all the points raised. Colonel Hutchinson referred, among other things, to a car in 1902 concerning which he had some evidence

of shimmy or wobble. A great many people, now that wobble was spoken about, thought they could remember it occurring in cars in years gone by. As a matter of fact, in most of these cases it was not either wobble or shimmy; it was the action of the impulse imparted by the wheel to the steering arm centre. It was these stresses which Dr. Lanchester lessened (so far as the hand on the steering lever was concerned) by using a weight of lead of some five pounds. Mr. Ricardo in a general way, he thought, agreed with what he said in regard to the expenditure of a very great deal of ingenious and well-directed effort in the making of the modern small high speed and high power engine, although, perhaps, he would not agree with his remarks to the effect that some of that progress had been arrived at by the application of ideas resulting from the experiments of steam engineers. Mr. Parnacott had told them a great deal and had shown them a number of diagrams, but inasmuch as he had in June, 1920, given a complete explanation of the cause of wheel wobble, and that explanation had apparently not been accepted even by such good authorities as several well-known members of the Institution of Automobile Engineers, he thought that Mr. Parnacott was a little mistaken as to what was a complete explanation of the cause of shimmy or wheel wobble. As to the independent springing which he showed them, he was not the only supporter of the idea of separate springing for separate wheels. There was one car for instance, which had no leaved springs at all, but a vertical coil spring. Colonel Hacking had a very wide experience and knowledge. On the whole he appeared to agree with him (the lecturer) as to the question of horse-power taxation. The Master of Sempill mentioned among other things free-wheel gearing. Numbers of free-wheel arrangements had been tried, and one or two of those which were most likely to stand practical use in real heavy work were now on experiment. One might conclude from what had been done that the free-wheel and the free-wheel chain arrangements were already known to be practically successful. All he could say in regard to it was that it was very much like many other things. They could not be certain that they were quite satisfactory until time had proved the wearing capacity of certain parts. He could not possibly say that all vehicles would hereafter be fitted in that way. With regard to Major Beaumont's remarks, they all agreed that many English firms had shown themselves quite ready to go to very great expense to adopt the best means of arriving at satisfactory practical results by means of experiments, and they had been ready to listen to those who had made special studies and experiments in any one direction.

On the motion of the Chairman, a hearty vote of thanks was accorded to Mr. Beaumont for his very interesting paper, and the meeting then terminated.

NOTES ON BOOKS.

AEROPLANE PHOTOGRAPHY. By Clarence Winchester and F. L. Wills. London: Chapman and Hall, Ltd.

In embarking on any undertaking, it is always advisable to set to work upon a definite plan with a definite object in view.

In this book the authors have embarked on a very considerable undertaking, without, it would seem, any particular plan, or any very definite object in view. They have collected a great mass of information, much of which is put before the reader in a very admirable way, but, taking the book as a whole, the impression left is one of incoherence.

The information is undigested and the chaff is mixed up with the wheat, with no hint to the uninitiated as to how it may be separated.

A considerable part of the book is devoted to description of apparatus, much of which is not strictly aerial photographic apparatus at all. These portions of the book savour too much of the salesman's catalogue, but are less useful, in that no mention is made of the all-important consideration of price.

Included also in this part of the book is a good deal of mapping apparatus, which, though extremely interesting as examples of the mechanical expression of geometrical and optical principles (which, incidentally, are not stated) is probably of no practical value whatever. On the other hand, the list of mapping equipment is by no means exhaustive and some of the most useful and interesting instruments now in use are not mentioned.

There is, in fact, a good deal of evidence in the book that the writers have not entirely shaken free of the illusion, so common among airmen after the war, that aerial photography and photographic survey are different names for the same or very similar things.

Admitting that aerial survey promises to be the most important offshoot of aerial photography, it is quite a distinct subject, to which justice can only be done by those who really know something about it. It may be suggested, therefore, that it was a mistake to devote so much space to giving what is after all a very partial and incomplete view of this very important science.

As regards the remainder of the book, the chapter on the industrial applications of aerial photography is interesting, but perhaps the best thing in it is the chapter on aerial photography in relation of archæology.

The book is very well got up and is illustrated with a large and well-selected collection of photographs—aerial and other—admirably reproduced. It is not, however, cheap. When one remembers that it is certainly not an authoritative text book, but yet contains so much technical matter, that it can hardly be called a "popular" account, one may be pardoned for suggesting that the purchase money might be expended to more advantage in other ways.

THE PORTRAIT OF SIR JOHN SOANE. By A. T. BOLTON. London: Published by Sir John Soane's Museum. 16s. net.

Sir John Soane, architect and antiquarian, a man who left a mark on his age, was born near Reading in 1752, the "son of a bricklayer or small builder." Mr. Bolton tells us that the name was then written Soan; in the Dictionary of National Biography it is given as having been Swan. Now in the introduction Mr. Bolton says that "a distinguishing mark of Soane's character was that of possessing to the full the characteristic Hebrew passion for righteousness." Are we to gather that Soane was of the same race as the "Swann" of Marcel Proust, and as the great Baroque architect Daniel Pöppelmann? He had a personality difficult to sum up because of the moods which were apt to cloud over his real qualities; he was temperamental, a devoted husband, able to show uncompromising antagonism. If indeed he had Jewish blood in his veins it would be interesting to compare his reactions after the death of Mrs. Soane with those of Disraeli in similar circumstances. "Humanly speaking, Soane seems to have been restored to some renewed appreciation of life, and to a revived interest in his art, through the merciful intervention of a small group of ladies."

His life was a notably full and successful one. He lived to a great age, managing, like a comparatively small number of artists, to combine creative work with filling a niche in conventional society; giving lectures, presiding over learned gatherings,

and so forth. In 1772 the bricklayer's son, at the age of nineteen, won the silver medal of the Royal Academy. He was only thirty-five when he was appointed architect to the Bank of England. Eighteen years later came his election as Professor of Architecture to the Academy, and from this time on he was making the important collection of antiquities (in the spirit of a Lorenzo de' Medici) which he afterwards bequeathed to the state. He died in 1837, at the age of eighty-four.

Thus Sir John Soane belonged to a very rich period of English history, a period both virile and sophisticated—adjectives which nowadays are not so often bracketed. The latter part of the eighteenth century was the heyday of urbanity in architecture, the heyday of the grand manner, a time, also, fruitful of works of art other than architectural. On the numerous men and women of note with whom Soane was brought into contact the letters collected by Mr. Bolton throw an intimate light; on their customs, too. "I have received, my dear Sir," writes someone to Soane, ". . . Your polite invitation for thursday next at $\frac{1}{2}$ p 6."

A favourite pupil of Soane's was George Basevi, first cousin of Disraeli and contemporary of John Soane, Junior. "All would have been well," says Mr. Bolton, "if George Basevi had been Soane's own son. His letters bear almost the dates of John Soane Junior. . . . Their contrasting tenour must have increased his (Sir John's) sense of personal disappointment. Soane had the Napoleonic desire to found a dynasty." He envied Nash, about whom, however, a Dr. Walcot wrote.

Master Nash, Master Nash,

You merit the lash

For debauching the taste of our Heir to the throne;

Then cross not the seas

To rob the Chinese

But learn to be wise from VITRUVIUS AND SOANE.

P.B.

THE FRIARS IN SUSSEX: 1228-1928. By E. B. Poland. Combridges: Hove, 12s. net.

The friars first came to England seven hundred years ago. They were suppressed by Henry VIII, but reappeared less than a hundred years after the Act of Supremacy. Thus they have lived and worked in the country for the best part of six centuries.

Mr. Poland's book is published at a time when the great majority of people in these islands take for granted a conception of life very different from the one represented and supported by the friars, and when Sussex, the labours of Mr. Hilaire Belloc notwithstanding, is little preoccupied with the history and evolution of the four Orders vowed to poverty. Nowadays it seems eccentric not to be vowed to the acquisition of wealth.

But there are not an infinite number of conceptions of life, and though the world may not revolve in regular cycles, as the ship's carpenter in "Mr. Midshipman Easy" believed it did—together with certain Greek philosophers—it is not a foregone conclusion that poverty must continue to remain unrespectable, nor a sure thing that the sort of spiritual background suggested by the friars has been for ever laid aside.

We are not so enchanted by our civilisation, by the moral air we breathe in our impatient cities, as to be able to think unsympathetically of men whose lives were simple and devoted. And after all, a saint like Francis of Assisi belongs to all countries and to all sects; we need not be shy of the subject of friars, even if we are not Roman Catholics. Mr. Poland has slightly provocative moments, indeed, but

as these are expressions of feeling and not in the form of argument, we can excuse them and read on.

The Dominicans, as is well known, were founded by Dominic Gusman, who had been much shocked by the Albigensian heretics—a body of people who, according to humanistic standards, were agreeably civilised, surprisingly so for their epoch. But the Dominicans or Preachers had other objects besides the suppression of heresy, and within the lifetime of their founder a Province of the Order was set up in England. In Sussex priories were established at Arundel, Chichester and Winchelsea.

The Grey Friars of Saint Francis also settled in Chichester and Winchelsea, and in Lewes besides. They landed in England in 1224, under Agnellus of Pisa, who had been specially appointed by Saint Francis himself. This holy man appears to have had a low opinion of learning when he first arrived, but a visit to Oxford made him change his mind, and he went so far as to build a school.

The first General European Chapter of the Carmelite Order was held at Aylesford, in Kent, in 1247, the reorganiser being a Kentish man, St. Simon Stock. In 1316 Sir John de Mowbray founded the priory at Shoreham.

The Hermits of Saint Augustine, or Austin Friars, reached England about the middle of the thirteenth century; Rye was one of their centres. Two-and-a-half centuries later they received the following testimonial from Henry VIII himself. "So much does he (the King) admire their holiness of life that he finds it quite impossible to describe their merits as they deserve. They present an ideal of Christian poverty, sincerity, charity."

The king expressed a sentiment that was certainly felt by the poor with regard to the Austin and other friars. Even the reputedly bloated monks were sufficiently popular at the time of the Reformation for risings to break out in their favour, but on the whole by that stage the enclosed orders had lost sympathy, while the friars had kept it. It was certainly unfair, as Mr. Poland says, of people to accuse the friars of having become "sturdy beggars," they had always been beggars. They were not to blame if every tramp tried to pass himself off as one of their order.

Mr. Poland summarises the activities of the friars as follows. "With the Franciscans work took the character of Ministering; with the Dominicans, more of Preaching and Teaching; with the Carmelites and Austin Friars, a less distinctive specialisation and a more general character. But with all the Friars, Mission Work was their object." Later, he says: "The Friars' aim was to be Christlike; that aim they strove to attain by the renunciation of everything the twentieth century desires most." They had, in fact, two objects or aims. They wished to lead a certain kind of life for its own sake, and they wished to make themselves useful to humanity. To give service without thought of payment is clearly in some ways more admirable than to give service in exchange for mansions and a fleet of cars; the wisdom of to-day is to exploit even the smallest advantage financially. It was the logic of the situation that made Henry VIII abolish the Orders in England; they had accumulated hardly anything that it was worth his while to seize.

Mr. Poland becomes a little disingenuous when he asks us to "disabuse our minds" of "some things" before judging of the success or failure of the Mendicants. "First there are the wit and sneers of writers like Chaucer, who represent the friar as a disreputable Friar Tuck sort of person." "Writers like Chaucer" is amusing. Is *that* the way to speak of the venerable Father of English Literature? "This class of writers . . ." Mr. Poland continues. And then: "Similarly, we must disregard Wyclifs, ancient and modern." Visions of a world overrun with Chaucers and Wyclifs.

All the same, Mr. Poland agrees that the friars "were not in 1530 what they had been in 1230." But "to speak of the decline as a decay is to use too strong a word." There was a "slight departure from St. Francis' rather unpractical love of poverty." Now who is the author of this interesting book that he should criticise St. Francis' love of poverty with such easy assurance? I should like to refer him to the story of the Grand Inquisitor in "The Brothers Karamazov."

Early in the seventeenth century the friars came back to England. The Dominicans owed their re-establishment largely to the zeal of Philip Howard, afterwards Cardinal Howard, a convert, and grandson of the Earl of Arundel. The Franciscans were also revived by a convert. The Carmelites came back in 1615, but in 1849 their English Province came to an end for the second time for lack of recruits. Thirteen years later, however, a converted Jew, Father Augustine, founded a community once more. The Austin Friars did not return after their suppression till the middle of the nineteenth century.

FIGURE CONSTRUCTION. By A. Bement. London: Gregg Publishing Co. \$2½.

Education is a sort of scaffolding. Systems are meant for us to grow out of. They do not, so to speak, say the last word on any subject; they indicate its possibilities. Thus Professor Bement's four assumptions are provisional, disciplinary, not final.

First, it is easier, he says, to draw the figure in action than in half-action or in bi-symmetrical attitudes. Criticism might here have something to say about "easier." Easier or more difficult—that is surely not the point. Then secondly, except when seen from the front, the action of the body may be expressed . . . by two lines, a convex and a concave curve. As to that, we need not quarrel with Professor Bement; here is his system, scaffolding or discipline. Thirdly, the figure as a whole should be studied before the detailed parts. Undeniably. Unity and design reside in the whole rather even than in the sum of the parts. Fourthly and lastly, students should draw quickly, "for great artists have been masters of technique, and technique presupposes skill, which in turn presupposes speed." All the same, how long is Leonardo understood to have taken over his Mona Lisa?

The method of counting for strokes recommended to instructors in Lesson One is a little disconcerting. It may come congenially to a certain type of pupil, but not, one suspects, to the budding genius, who will perhaps be antagonised by the suggestion of drill.

Lesson Four begins with the interesting piece of information that a researcher for the Provost Marshal's Office at Washington discovered 115 published methods of measuring the human form. An "easily remembered scale of measurement" put forward by Professor Bement "is one in which each extremity is estimated to be three-quarters of the one above. Thus the hand is three-quarters of the fore-arm, the fore-arm is three-quarters of the upper arm, etc." The questions set at the end of this and other lessons are a little disingenuous. "Have you ever seen anyone who is eight heads high? What is the normal size of the head to-day?"

Professor Bement concludes with a number of reproductions of famous pictures and statues on which he comments. But when he says of the head of a boy by Andrea del Sarto: "it is a very appealing little face, well worth study from that point of view alone," it is hard to follow him. There are also several photographs of nudes and men and women in action: dancing, diving, and so forth.

EXHIBITION OF ANTIQUES AND WORKS OF ART

organised by

THE DAILY TELEGRAPH

Olympia, London, July 19th to August 1st.

The largest and most comprehensive display of antiques of all kinds ever gathered under one roof will be seen at Olympia, London, from July 19th to August 1st. The occasion is the first International Exhibition of Antiques and Works of Art, organised by *The Daily Telegraph*, of London, under most distinguished patronage. The Exhibition will be unique in that it will include both dealers' exhibits, which will be for sale, and loan exhibits, privately owned. Many of the loan exhibits have never been seen by the public. They are from collections which even few connoisseurs have been privileged to see.



[By kind permission of the Bunnell Gallery, 41, Ebury Street, S.W. 1.]

A pair of Historical Red Lacquer Cabinets, 18th Century: Presented to the Viceroy of "The Yellow Jacket" by Citizens of Nankin. Centre Cabinet A.D. 1730: Exquisite Fine Red Lacquer. Vase in Red Lacquer: Very fine about A.D. 1760.

The idea of holding such an exhibition originated in the office of the *Bazaar, Exchange and Mart*, Connoisseurs' Edition, and was later taken up most enthusiastically by *The Daily Telegraph*, with the support of other newspapers under the control of the companies of which Sir William Berry, President of the Council of

the Exhibition, is head. The vice-presidents include nine ambassadors at the Court of St. James', and a host of most distinguished collectors and art lovers, including Earl Beauchamp, Viscount Esher, Viscount Burnham, Viscount Lee of Fareham, Viscount D'Abernon, Viscount Ullswater, Lord Desborough, Lord Rochdale, Lord Dewar, Sir James Gomer Berry, Sir Lionel Faudel Phillips, Sir Frank Dicksee, P.R.A., Sir Robert Witt, Sir Martin Conway, M.P., Sir Edward Iliffe, M.P., Sir Edwin L. Lutyens, R.A., Sir David Murray, R.A., Sir Charles Allom, Mr. J. Ramsay MacDonald, M.P., and Mr. Edward Knoblock.

There is also a distinguished Council, a prominent member of which is Dean Inge, and an Executive Committee of art experts and business men presided over by Sir Herbert Morgan, himself a connoisseur, with Lt.-Col. E. F. Lawson, of *The Daily Telegraph*, as chairman of the Finance Committee.



[By kind permission of the Bucknall Gallery, 41, Ebury Street, S.W. 2.]

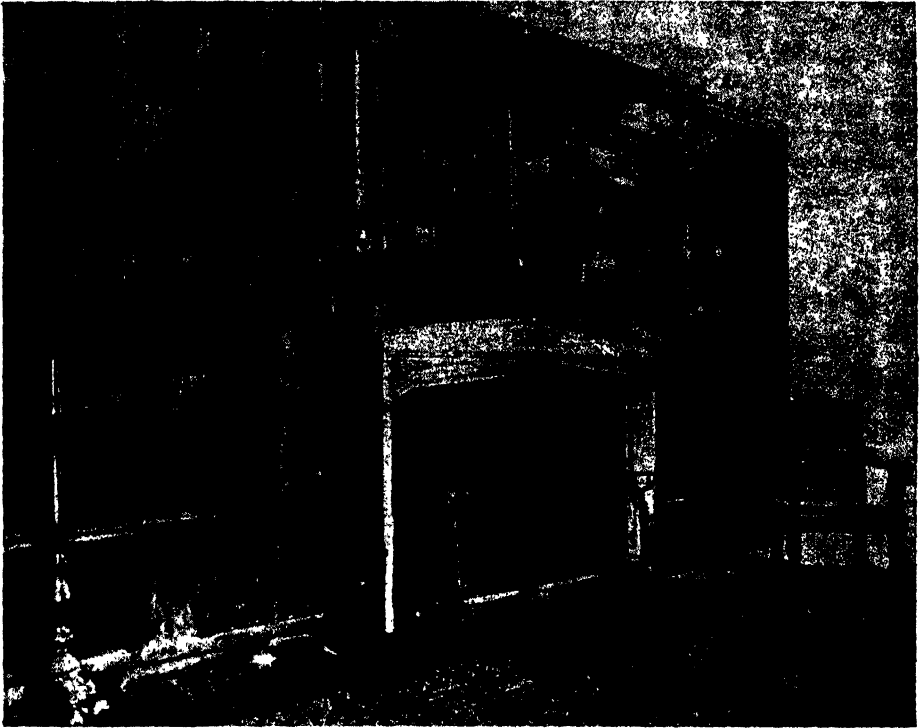
A Ming Torquoise Porcelain Dragon. An important and unique piece, suitable for Museum.

Mr. Sydney Carroll, who has carried the organisation through since its inception, is Honorary General Director; Sir Martin Conway, M.P., is Honorary Director. Loan Exhibits, with Major E. A. Belcher and Miss M. Jourdain to help him, and Mr. Joseph Emberton is the Exhibition Architect. Sir Charles Allom is Honorary Director, Period Rooms.

The Exhibition is intended to help in developing the growing appreciation of the work of the craftsmen of long ago and to add to the prestige of London as the art centre of the world. The whole of the ground floor of the main hall of Olympia

was taken in order that the Exhibition might be comprehensive and in order that there should be plenty of room for the general public. It was a bold step which has been amply justified by the enthusiasm of dealers and collectors alike. The difficulty has been, not to fill the huge hall, but to keep the exhibits within the limits of the available space—and this without allowing in anything which is not genuine and worthy of the occasion.

How important is the trade section may be judged by just a few of the names of dealers who have stands—Moss Harris, Spinks, Frank Partridge, Rochelle Thomas, Keeble, and so on. Besides such famous dealers, there are many other



[By kind permission of the Bucknall Gallery, 41, Ebury Street, S.W. 1.]

Crest room exhibited by Edwards & Sons, Ltd., Regent Street. Circ. 1620. One of the few known examples of early oak-panelled rooms, decorated in gold and colour, with quarterings of the family.

less well-known firms from the provinces. With their exhibits shown almost side by side, and with the critical eyes of experienced connoisseurs upon them, it is only to be expected that the dealers are keeping the very pick of their show-rooms for display—and sale—at Olympia. It is part of the movement to widen the ranks of lovers of antiques—as well as being a sound commercial proposition—that many of the dealers are showing also genuine old furniture at moderate prices.

A feature of the loan section is the gallery containing some 60 pictures, all of them of real importance. Mr. Alec Martin, of Messrs. Christie, Manson & Woods,

Mr. R. R. Tatlock, editor of *The Burlington Magazine*, Mr. Frank Rutter, art critic of *The Sunday Times*, and Mr. A. C. R. Carter, of *The Daily Telegraph*, form the distinguished expert committee which has selected the pictures from the numerous generous offers. Outstanding pictures will be the Raphael "Madonna and Child," which Sir Joseph Duveen is lending; Van Dyck's "Abbé Scaglia," which Sir William Berry bought at the recent Holford Sale; Rembrandt's "Savant and the Bust of Homer," which Sir Joseph Duveen has brought back from America after over 30 years' absence; John Crome's "Willow Tree," recently recaptured from America by Mr. P. M. Turner, of the Independent Gallery, on behalf of Mr. James Hardy; Raeburn's "MacNab," the property of Lord Dewar; the famous "Wilton Diptych," the earliest landmark in the history of English painting; one of the finest portraits by Sustermans; two Titians, a Reynolds, a Gainsborough and a Quentin Matsys. The aim has been to collect the finest examples of the painter's art rather than a large collection of less prominent works and to choose, as far as possible, those pictures which cannot be seen in any museum or public gallery.

Furniture, of course, will fill several stands in the loan section. Among those who are lending it are Lord Rochdale, Sir Gomer Berry, Mr. Stephen Winkworth, Mr. H. Clifford Smith and Mr. Henry Hirsch, all of whose collections are well known. There is a small sculpture section, including a Michael Angelo. Old English china and glass, old Dutch Delft, including the famous Twisk Plate, signed and dated 1742 by Michael Van Kuyk, and some rare pieces of early Chinese dynasties, fill another stand.

Over a thousand domestic wooden objects, some of them shaped in a most delightfully primitive manner, dating from 1400 to 1800, are be lent by Mr. Evan Thomas. They are in themselves a history of English home-life through those four centuries. Mr. Howard Cotterell has organised what is said to be the finest collection of old English pewter ever shown. Mr. F. J. Melville has arranged a most valuable display of the earliest postage stamps.

Other loan exhibits include old locks and keys from the Birmingham Museum; historical relics of all kinds; relics of 3,000 years ago—dug up in London excavations or found in the Thames; old model ships; boots and shoes dating from Roman to Tudor times; and a priceless collection of old silver, including some from Lord Desborough's home at Panshanger.

Sir Charles Allom has arranged a series of period rooms, decorated and furnished with contemporary loan exhibits. A Gothic hall and staircase is to be hung with tapestries from Lord Rochdale's house. There is to be a Tudor linenfold room; an Elizabethan bedroom; a James I living room; a Charles II room; a Georgian hall and staircase; and a late Georgian drawing room.

Flanking these rooms will be two old-fashioned gardens.

Olympia lends itself to displays on a very big scale and still leaves plenty of room for crowds to circulate and see everything. It is to be open each day from 10 a.m. to 10 p.m. The charge for admission on the first day is to be 10s.; on Friday, July 27th it will be 5s.; and on all other days 2s.

The total value of the Exhibition runs into several million pounds sterling, and special precautions are being taken for the safety of the exhibits.



OLYMPIA
JULY 19TH to AUGUST 1ST
10 a.m. to 10 p.m.
GREAT
EXHIBITION *of*
ANTIQUES
&
WORKS of ART

Organised by

The Daily Telegraph

¶ Treasures of all the ages, Pictures, Furniture, China, Tapestry—objects which master craftsmen of the past made for lovers of beauty—these are what you will find at Olympia, an incomparable collection.

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FRIDAY, JULY 20th, 1928.

*All communications for the Society should be addressed to the Secretary, John Street
Adelphi, W.C.(2.)*

NOTICES.

COUNCIL.

A meeting of the Council was held on Monday, July 9th. Present:- Sir George Sutton, Bt., in the Chair; Sir Charles H. Armstrong; Mr. Llewelyn B. Atkinson, M.I.E.E.; Sir Charles Stuart Bayley, G.C.I.E., K.C.S.I.; Captain Sir Arthur Clarke, K.B.E.; Mr. Peter MacIntyre Evans M.A., LL.D.; Sir Edward Gait, K.C.S.I., C.I.E.; Sir Alexander Gibb, G.B.E., C.B.; Sir Herbert Jackson, K.B.E., F.R.S.; Sir Humphrey Leggett, R.E., D.S.O.; Sir Philip Magnus, Bt.; Mr. James Swinburne, F.R.S.; Mr. Alan A. Campbell Swinton, F.R.S.; Mr. Carmichael Thomas; Sir Frank Warner, K.B.E., and Sir Alfred Yarrow, Bt., F.R.S., with Mr. G. K. Menzies, M.A. (Secretary), and Mr. W. Perry, B.A. (Assistant Secretary).

Sir George Sutton was unanimously elected Chairman of the Council for the year 1928-29.

Sir Richard Redmayne, K.C.B., and Mr. W. U. J. Woolcock, C.B.E., were elected members of Council in place of Sir Edward Davson, Bt., and Sir John Dewrance, K.B.E., who were unable to serve.

A prize of £30 under the Thomas Gray Memorial Trust was awarded to Cadet-Captain John Herbert Chalk, of the Nautical College, Pangbourne.

An offer from the Mitchell City of London Educational Foundation of a Travelling Scholarship in Spanish to be awarded in connexion with the Society's Examinations was gratefully accepted.

The total number of entries for all the Society's Examinations in 1928 was reported, viz., 100,048.

Progress in connexion with the judging of the work submitted at the Fifth Annual Competition of Designs was reported.

Arrangements for the forthcoming session were considered.
A quantity of financial and formal business was transacted.

The following candidates were duly elected Fellows of the Society:—

Angus, Jonathan, M.Inst.C.E., London.
Bettmann, S., J.P., Coventry.
Douglas, Charles E., M.I.Mech.E., London.
Goode, John Henry, M.C., Sydney, Australia.
Hamp, Stanley, F.R.I.B.A., London.
Haw, James Herbert P., London.
Hooper, Lewis G., New Orleans, La., U.S.A.
Knight, Miss Ernestine, Exmouth, Devon.
Maginnis, Charles D., Boston, Mass., U.S.A.
Mamujee, Adamally, Bambalapitiya, Colombo, Ceylon.
Osborn, Edward Thomas, Seattle, Washington, U.S.A.
Prior, Captain C. L., London.
Saville, William George, London.
Sellers, James Henry, Manchester.
Shearer, Major A. B., Disley, Cheshire.
Skull, Fred, High Wycombe, Bucks.
Todd, John L., M.D., C.M., D.Sc., M.R.C.S., L.R.C.P., Senneville, Quebec, Canada.
Thompson, Captain W. A., R.N. (retd.), London.
Wigglesworth, Alfred, London.

DOMINIONS AND COLONIES SECTION.

A meeting of the Dominions and Colonies Section was held on Wednesday, June 27th, to consider the arrangements for meetings of the Section during the forthcoming Session. The following were present:—Sir Philip Magnus (in the Chair); Major Sir Humphrey Leggett, R.E., D.S.O.; Admiral J. de Courcy Hamilton, M.V.O.; Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S.; Mr. Carmichael Thomas and Mr. Hanns Vischer, with Mr. G. K. Menzies, Secretary of the Society, and Mr. W. Perry, Secretary of the Section.

PROCEEDINGS OF THE SOCIETY.

INDIAN SECTION.

FRIDAY, JUNE 8, 1928.

SIR CHARLES C. McLEOD, Bt., in the Chair.

The following paper was read:—

THE PORT OF CALCUTTA AND ITS POST-WAR DEVELOPMENT.

By S. C. STUART-WILLIAMS, Chairman, Calcutta Port Commissioners.

The City and Port of Calcutta are situated at latitude $22^{\circ}33'$ north and longitude $88^{\circ}20'$ east on the river Hooghly—roughly at the limit of navigation for large ocean-going vessels, and about 120 miles from the open sea. The river Hooghly is the westernmost of the channels by which the waters of the Ganges enter the Bay of Bengal, but it is not fed directly by the Ganges. It is itself the result of the junction of three water-courses, the Bhagirathi, Jalangi and Matabhanga, which are the first deltaic offshoots of the Ganges. Of these three headwater rivers the Bhagirathi is the most important, both by reason of the greater quantity of Ganges water which it conveys and also by reason of its four tributary rivers draining the country on the west. Below Calcutta, the Hooghly is reinforced by four tributaries, all on the west, namely, the Damodar, Rupnarayan, Haldia and Rasulpur, and its separate existence ceases at Saugor, some eighty miles below Calcutta. Saugor Island, however, is not immediately contiguous to the open sea; the navigable channel continues for over forty miles over the Middleton bar to the Sandheads, which are some 120 miles from Calcutta, where the Pilot brig awaits the incoming steamer.

The jurisdiction of the Calcutta Port Commissioners is of two kinds, namely, that within the port proper, which now commences at Konnagar, eight miles above Calcutta, and terminates at the subsidiary oil port of Budge Budge, thirteen miles below Calcutta, and also the more limited jurisdiction over the headwaters of the river and Port Approaches, the former of which commences at Kalna, seventy miles above Calcutta, terminating at the upstream limit of the port proper, and the latter commencing at Budge Budge, and terminating at the Sandheads. The whole of their jurisdiction thus comprises nearly 200 miles of the river proper, its headwaters and the estuary.

The river Hooghly is a navigable channel characterised, from the point of view of configuration, by the devious course common to deltaic rivers. As will be seen from the map, the channel from Calcutta to the sea, is one marked by constant curvature, particularly in its upper reaches. From the hydraulic point of view, it is characterised by a sharp distinction between the dry season, from October to June, during which the influence of the flood tides are predominant, and the wet season, from June to October, during which the ebb tide is predominant, in the sense that the downward flow of the waters derived from the Ganges itself, from the three Nadia rivers and their tributaries and from the four western tributaries of the Hooghly below Calcutta, is sufficient to produce a marked scour in the ebb tide channel, and to hold up the influx of the ordinary flood tide. By its possession of this fresh water discharge, never altogether absent, and attaining great importance during the rainy

season, the Hooghly is differentiated from deltaic rivers which begin and end within the delta, as, for example, the Mutlah river, which adjoins it on the east and which was at one time considered a more dependable channel of navigation. On the other hand, by virtue of the strong tidal influence extending for many miles above the Port, it is differentiated from those river ports which are situated practically at the head of tidal influence. The equilibrium of its channel, therefore, depends on the preservation and balancing of its fresh water discharge and of its tidal flow, and it is from this standpoint that the control of the river's regime is regarded by the Port Commissioners; that is to say, it is their settled aim and policy to watch over and safeguard the headwaters supply on the one hand, and the tidal reservoir up to, through and above the port on the other. Reliable figures showing the comparative strength of the ebb and flow are not readily obtainable. Fairly careful estimates were framed by Professor Vernon Harcourt during his examination of the river and its problems in the years 1895-96, and these work up to a grand total of fresh-water discharge during the year at the mouth of the estuary of about 200,000 million cubic yards—which is believed to bring down about fifty million cubic yards of silt content.

As regards the tides, there is a mean range of greatest ordinary spring tides of 14.2 ft. at the mouth of the estuary, 15.8 ft. at Diamond Harbour, and 11.7 ft. at Calcutta. The volume of water entering the Hooghly at a high spring tide in the dry season is estimated at 244,000 cubic yards per second, or more than $4\frac{1}{2}$ times the maximum fresh water discharge at the highest flood. There is, however, a rapid decrease in the narrower part of the river approaching the port and the tidal influence there in the dry season is probably not more than about 14,000 cubic yards per second. Even during the freshet months, when the maximum fresh water discharge is attained, estimated at about 54,000 cubic yards per second, the tidal influx is estimated at more than 200,000 cubic yards per second, or nearly four times as much, and the tidal flow during the four driest months of the year amounts to more than double the total fresh water discharge in a year. In the rainy season, even at lowest neap tides, some tidal water enters the estuary and owing to the large influx at high spring tides, the total during the rainy season is believed to be not much less than during the dry months. These statements apply of course to the estuary; in the upper parts of the river the tidal influence is small during the rainy season, though during the dry season it predominates all the way between Nadia and the sea.

As a navigable channel the Hooghly does not enjoy the best of reputations, and the popular idea, which centres round the "James and Mary" shoal, situated near Hooghly Point, as the most dangerous place on the river, is not far from the truth. Taking first the simpler case of vessels entering the port. Their first contact with the Administration is on the arrival of the vessel at one of the three outer light-vessels, which in order from west to east are called

the Pilot's Ridge, Eastern Channel and Mutlah, the first of which is that ordinarily encountered by vessels coming up from Madras and Colombo, and the last mentioned by those coming from Chittagong or Rangoon. Calcutta being in almost all cases a terminal port, vessels are not usually laden to their maximum draft on arrival there and this facilitates their journey up the river, where they have to encounter in turn the Middleton Bar lying to the south of Saugor Island and Lighthouse, the Gabtola, Jellingham, and Balari Bars in the estuary and the Eastern Gut and Moyapur Bars in the upper portion of the river. The navigable channel is lit by a chain of light-vessels attended or unattended, and of boat-buoys and buoys, mostly of the Aga type, all the way from the Sandheads to Hospital Point above Diamond Harbour, while for day use there are elaborate systems of river marks on both banks, both to define the tracks across the various Bars and Crossings and for surveying purposes. There is no lighting above Hospital Point, where the width of the channel is less, but any vessel possessing fair speed is able to reach Calcutta from the sea on the one tide provided that she can cross the governing bar and can complete the run in daylight. In the downstream or seawards direction the problem is naturally more difficult; vessels are more deeply laden and are meeting the tide, not moving with it, and the first part of the journey is complicated by the necessity for crossing the Eastern Gut (James & Mary), more or less at high water, which again has its bearing on the passage of what are known as the low water crossings just below Calcutta. Vessels, however, are now enabled by means of night navigation to perform the whole of the journey in two tides, save when the conditions are unusually unfavourable or the draft is unusually deep.

The Commissioners have always devoted great attention to the survey of the navigable channel, and it is a picturesque and interesting fact that the River Hooghly Survey Department—founded in 1668—is the oldest public service in India. The necessity for an elaborate system of survey work need hardly be emphasised in the case of an alluvial river like the Hooghly, subjected to exceptional movements of water in both directions, from torrential rain and violent spring tides accompanied by bores, and certain of the bars are from natural causes subject to great fluctuations in depth which would endanger the safety of ships unless they were protected by every available precaution. There are altogether four survey parties, namely, the Upper Reaches and Town Survey Party, the Hooghly Point Party, and the Middle Reaches and Estuary Parties, while surveyors are also carried on the three suction dredgers which are constantly at work. The whole of the navigable channel is plotted out and the series of charts or plans thus produced, and kept up-to-date with great care, are before the Pilot throughout his journey. The use of suction dredgers has been in force for more than twenty years and the Commissioners' fleet at present comprises three vessels, namely, the *Gunga* and *Balari*, both of the suction dredger type, with hopper discharge, and the *Sand-piper*, a suction dredger with pipe discharge.

So far, in referring to the City and Port of Calcutta, I have treated its site as an accomplished fact. But the suggestion has been made in the past, and from time to time recurs, that the site of Calcutta was a fundamental mistake. This suggestion is picturesquely embodied in Kipling's couplet :

" So Charnock's midday halt, more's the pity,
Grew a city "—

in allusion to the legend that Job Charnock, resting under a tree by the river bank during his third visit, made in 1690, fixed the exact site of his future operations at the present site of Calcutta ; this tree is commonly located somewhere near the site of the Howrah Bridge on the eastern bank, and thus, it is supposed, was determined the site of one, and eventually, the most important, of the group of villages, Calcutta, Santanati, Gobindpur, Salkia, Chitpur, and Kalighat, which have become the city of Calcutta with its total population, including Howrah, of 1½ million people. It would seem that the choice of this site, so far as it rested with the European community, is due to two main reasons (a) the fact that the river at the site of the present Howrah Bridge was at its narrowest, and therefore most easily crossed, (b) that, of all the places to which ocean-going vessels could then proceed (the most important of which were Barnagore, Serampore, Chandernagore, and Hooghly), Calcutta offered by far the best anchorage, since the Calcutta Reach—known as the Long Reach—had deep water along the eastern bank from the site of the Howrah Bridge right down to Garden Reach, and in this stretch of water could easily accommodate hundreds of vessels of that day ; while from the point of view of the Indian community, the vicinity of this site to Kalighat and the sacred stream, the Adigunga, was a favourable contributory factor. My own view is that if the whole question could be reviewed, in the light of present-day knowledge, it is at least doubtful whether this site could be bettered. Up to the early years of the present century, there was one powerful argument in favour of a site at or below Diamond Harbour, namely, the serious obstacle to navigation presented by the James & Mary Bar, or the Eastern Gut, which underwent violent and serious variations for which there was then no human remedy. Thus, Pilot Beaumont in 1854 stated that the water over the Bar fell to a depth of 3 ft. to 4 ft. at low water in March, and the River Surveyor, Bedford, spoke of the low water depth varying from 4½ ft. to 21 ft. within a year. With the modern suction dredgers now in use such marked variations do not occur, and those which do occur, yield to the work of the dredger, so that this Bar remains usually at about 15 ft. or 16 ft. depth at low water and is nearly always better than the Middleton, which for almost every day of the year is the governing bar. As the other of the two upper bars, namely, the Moyapur Bar, is also generally in better condition than the Middleton, there is now no argument in favour of Diamond Harbour from the point of view of navigation. From

other points of view, namely, healthiness, proximity to up-country markets, to coal mines, to the jute and rice-growing districts, and greater safety from bores and tidal waves, all the evidence appears to point definitely to the selection of the present site.

The history of the Port may be divided, roughly, into four periods, three of which are past and the last of which merges into the present and immediate future. The first period (*a*) is that of the sailing ship pure and simple, lying at river moorings, unloading by boat and loading in the same way in a leisurely manner extending over months. Methods such as these were only applicable to valuable cargo, and the more valuable the cargo, the greater the incentive to theft, so that it was not long before the desire to avoid heavy losses by theft, and at the same time to be able to handle heavy and cumbrous articles, brought about the construction of the first Calcutta Jetties, which were devoted to the miscellaneous import trade. This brings us to (*b*), the second period, when the import trade was ordinarily handled at the jetties, with the exception of salt, taken by boat to the Salt Golahs at Salkia on the other side of the river, and coal, which was unloaded in Garden Reach, while vessels having discharged their imports, moved down the river to the moorings there to take on their cargoes of jute, gunnies, tea, shellac, linseed, hides and skins, and so forth. (*c*) But the increase of the import trade, the average value of which was, per ton, much higher than that of the export trade, brought about a corresponding increase in exports and thus a demand for greater facilities for the steamers which were then replacing the sailing vessels. Thus there came into existence towards the end of the "eighties," the Kidderpore Dock Scheme, which was to provide facilities for loading vessels both with general exports and with coal, which within a few years had sprung from a nominal to a valuable trade. In this third period, therefore, we have import steamers unloading either at the Calcutta jetties or in the stream, while the export trade is definitely and permanently established in the Kidderpore Docks, and with the growth of this export trade, the capacity of these docks was developed to its utmost limits, namely, a total of twenty-seven berths. Seventeen of these berths were devoted to the export trade or to special bag imports, chiefly sugar and rice, and ten to the loading of coal, all being served, both as regards the movement of ocean-going vessels and the enormous traffic in boats and lighters, by one 60 ft. lock, assisted by an 80 ft. gate which, however, could only be utilised at certain times and tides during the year. In this period the accommodation available may be said to have been definitely overtaken by the demands of the trade, a state of affairs which led to the appointment of a Committee of Enquiry, which reported in 1913, with the result that at the outbreak of war the Commissioners found themselves committed to a definite scheme of expansion involving an expenditure of many millions sterling, recommended by the Administration and endorsed by the Committee.

I come now to the fourth period (*d*), which commenced with the war and in

which we are still working. The war brought about a large reduction in the tonnage of vessels visiting the port, a huge drop in imports and the practical disappearance of the coal trade, leaving only the general export trade, that is to say, commodities used directly or indirectly in the war, in anything like a normal condition. The difficulties thus arising were accompanied by a serious drop in the value of the securities held by the Trust, which meant that the Sinking Fund was faced with a deficit of Rs.42 lakhs. Further, a considerable portion of the plant of the port was commandeered for service in other ports of the Empire. The third suction dredger then under construction, a number of cranes, railway wagons, launches, and building material were all commandeered, and although the Trust received compensation, the net loss then incurred reached a very heavy sum, owing to the unprecedented and unexpected costs of replacement. At the end of the war the Commissioners, therefore, had to replace large quantities of plant and material at abnormal rates, and to set about the work of proceeding with their development scheme, and this at a time when world prices were abnormally high and the cost of finance from 50% to 75% higher than in the pre-war period. In these circumstances it is no matter for surprise that little was done during the year 1919-1920, and, in regard to the more important parts of their development work, not much more during the following year 1920-1921, but by the year 1921-1922 the chief deficiencies in port equipment had been, or were being, made good. Of these, a third and more powerful suction dredger, fitted with hoppers capable of holding some 4,000 tons of spoil, a new despatch vessel, the sloop *Pansy*, for the surveillance and supply work of the light-vessels, buoys and marks a new ocean-going tug, a new and larger crane-vessel, a new fire-float, and important additions to locomotives and rolling stock, and crane and workshop equipment, form the principal items.

I have now to deal with the main part of the port development programme, *viz.*, the provision of additional accommodation to meet the increasing demands of trade. The Committee of 1913 had considered and finally rejected the extension of the Calcutta jetties southwards—a course which had obvious limitations, and would have commercialized one of the most picturesque portions of the city—and also the extension inland of the old dock system, already seriously hampered by its reliance on one lock entrance, and that all too small for the largest vessels using the port. They recommended the acceptance of the scheme of development already contemplated by the Administration, *viz.*, the construction of a new dock system in Garden Reach, to be preceded—in order to meet urgent requirements—by five riverside berths along the river front, behind which the new dock system would lie. When the war broke out work on these berths had already commenced, but was interrupted by the great hiatus which lasted from 1915 to 1920. The five berths were completed in 1923, and have now for some time been fully utilised. They comprise a coaling berth, built in replacement of a privately-owned berth belonging to

the British India Company, which it was necessary to acquire, and four general berths, capable of taking the largest vessels visiting the port. These latter consist of reinforced concrete and steel structures, provided with large double-storied transit sheds. The river at this point has a tidal range of 20 ft., but the bed has been dredged to allow from 35 to 40 ft. of water at the berths at low tide. On the wharf frontage, semi-portal electric cranes are provided, and electric cranes and lifts are also provided at the back of the sheds.

The remaining, and more important portion of the whole scheme is the King George's Dock. In its essentials, as already indicated, the scheme had been planned in the years which immediately preceded the war, that is to say, a scheme was contemplated with ample lock entrances placed obliquely in Garden Reach, just above the point known as Cumberbatchies Point, and with a dock running more or less at right angles to the river. Land had been acquired and cleared, and a certain amount of reclamation work already done during the period from 1910 to 1913, when Sir Frederick Dumayne occupied the post of Vice-Chairman which formed, at that time, with a Government Chairman, the head of the Executive, and Mr. Frederick Palmer was Chief Engineer. During the war the type of construction by large monoliths was more or less decided upon, and trial wells were sunk which gave valuable and, on the whole, reliable information as to the strata to be expected. In the years 1919-1920 and 1920-1921, the preliminaries were carried further, and detailed plans and estimates prepared by the Executive, with the valuable help and advice of Mr. J. Angus, the Commissioners' Consulting Engineer in London. During this preparatory stage the Commissioners decided, in view of the magnitude and importance of the scheme, to consult outside expert opinion, and were fortunate in obtaining the services of Sir John Wolfe Barry and Col. Cartwright Reid, in addition to those of Mr. J. Angus, to advise them on the methods of construction, and of Mr. Wentworth-Shields, of Southampton, to deal with the lay-out of transit sheds and warehouses, and the railway and road arrangements. The reports submitted by these gentlemen were of great value and assistance, and have played no small part in the final scheme. This comprises double entrances, *viz.*, a lock and a double dry dock, capable of being used as an emergency entrance, and in the first stage, six berths in the wet dock. The lock is 90 ft. in width with a usable length of 700 ft. The dry dock alongside has a total usable length of 1,156 ft. and is 80 ft. in width. It is divided into two portions by means of a floating caisson, the two sections providing lengths of 554 ft. and 569 ft. respectively, but capable of being lengthened by outer stop to 568 and 586 ft. respectively, and is designed so that ships can enter or leave from either end. The sill of the entrance lock will be at - 24, *i.e.*, 24 ft. below the datum line which is 2.5 ft. below lowest low water, so that at low water the depth on the sill will be $26\frac{1}{2}$ ft. and at highest high water $46\frac{1}{2}$ ft. The dry dock floor is being made at - $21\frac{1}{2}$ ft., giving a

depth at lowest low water of 24 ft. and $36\frac{1}{2}$ ft. at normal wet dock level, with 44 ft. at high water level. The wet dock is to be maintained at a level of +15 ft., with the bottom dredged to - 21 ft. The water level has been designed with a view to minimize pumping, but would, however, have involved a double set of gates, and to avoid the expense of these, it has been decided to use box caissons. Within the wet dock itself there will be in this—the first stage of the work—six berths altogether, *viz.*, a heavy lift yard, three import and one export berth for ocean-going ships, and a special berth for river steamers—with which it is hoped a large transshipment traffic will be carried on.

The information already available—coupled with that derived from the sinking of the three trial wells—pointed to the necessity for the utmost caution in constructing work of this magnitude, and at such depths, and for this reason the method decided upon—and endorsed by the consulting engineers—is monolithic, the wells being sunk independently until the outer ones rest on a stratum of stiff clay, and the remainder to a depth of about 52 ft. The main monoliths in the side walls of these entrances are 40 ft. square while the centre of the floor is made up of similar but smaller monoliths 36 ft. square with still smaller ones in the intervening spaces, and the walls of the wet dock have been constructed with wells of 44 ft. dimensions. All the masonry work has brought about an enormous demand for bricks which have been used literally by the million, and it is fortunate that almost all these could be made on the Commissioners' property at favourable rates. The blue bricks used on the facing of the wells have also been of Indian make—a fact which appears worthy of note, as this is probably the first large work on which locally made blue bricks have been used. The granite for copings, and for the caisson grooves has all been imported, some from Cornwall, and some from Sweden. The cement work has been almost entirely made in India, and the results obtained on the whole excellent. The machinery comprises three box-shaped caissons and two ship caissons—so designed as to provide at the minimum cost for any contingency at all probable, and of these the box caissons are moved by hydraulic hauling gear placed in a shallow pit on one side of the recess, while the ship caissons will be manipulated by tanks divided into two compartments by a watertight diaphragm which can be emptied by means of two electrically-driven centrifugal pumps, the current being supplied by flexible cable from the dock side.

It will be realised that it is hardly possible in a paper of this kind to deal adequately with this scheme, the details of which will be described later in a technical paper, and I must now leave this part of my subject, with the remark that it is now being pushed on to an early completion which we hope to see in the early months of next year.

I would, however, like to say a word as to the future. The area taken up and prepared in connection with the King George's Dock scheme makes ample provision for any likely development in the trade of Calcutta for many years.

Not only is the area demarcated for the extension of the wet dock itself capable of providing about twenty-five more berths—and the warehouse area of providing suitable sites for a corresponding tonnage of goods—but the additional area available for private trade depots is calculated to be sufficient for any possible extensions, while the further area marked off for railway purposes, *i.e.*, for a main marshalling yard, and for the subsidiary grids which will serve the different portions of the scheme as it develops, seem sufficient to deal with all likely demands on modern and economical lines.

I would like to revert for a moment to the old Kidderpore system. It will be remembered that I spoke of a single and inadequate lock entrance. One of the results of the visit paid by Colonel Cartwright Reid to Calcutta in 1919 was to bring home to the Administration the degree to which they were trusting to the one overworked lock entrance and the immediate necessity of giving it a complete overhaul after its continuous work of nearly forty years. Such overhaul could only be effected if the lock were thrown out of commission, and it could not be thrown out of commission without another entrance being provided. In the end, it was decided that an additional entrance must be provided, and that in the face of the greatest possible physical difficulties, the realisation of which had hitherto prevented such a decision. At the north end there is the open river with its large tidal range. At the south end there is the tidal basin with a fixed water level $61\frac{1}{2}$ feet above the underside of the lock floor, and $40\frac{1}{2}$ feet above the finished level of the floor. On the west side for a distance of 540 feet there is the old 60 ft. lock entrance with the underside of its floor 9 ft. above that of the new lock, and, beyond these, another 305 ft. of open river, while on the east side for a distance of 350 ft. there is No. 3 Dry Dock, the underside of the floor of which is 25 ft. above that of the new lock. In such circumstances it will be realised that work must be slow, but it is hoped to complete this additional lock, which was commenced in 1922-1923, some time in 1929, and it is satisfactory that though many difficulties have had to be met, they have so far been successfully surmounted.

I conclude with a few words as to the financial or economic side of this development work. Much money has been, and is being spent, and this fact carries with it a heavy financial responsibility. Our outlay has had to be incurred, moreover, partly in an abnormal period, both as regards the prices of material and plant, and as regards interest rates and exchange problems, and it is satisfactory to be able to point to the cordial support which the Administration has received from the Government of India, the Government of Bengal, the commercial community of Calcutta, and the banks in London and Calcutta, which have assisted in the arrangement of finance. I hope and sincerely believe that their confidence has not been misplaced. Although the effects of the war have been felt even up to the years 1924-1925, and 1925-1926, we may, I think, now feel a reasonable hope that we have got back to the pre-war position, and that the increases in tonnage which have marked

the last two years are permanent. I will not worry you with a recital of many figures, but I can inform you that during the last five years ended March, 1928, there has been an increase of 38 per cent. in the gross tonnage of vessels entering the port, and of 46 per cent. in the tonnage of goods handled, and that both figures are the highest in our history. The revenue and expenditure have increased, the former by 27 per cent. and the latter by 16 per cent. The Reserve Funds have been substantially increased, and are more than double the amount they had reached five years ago, *viz.*, Rs. 133 lakhs, as against Rs. 65 lakhs.

While the opening of the dock will mean an increased burden on the revenue account, it is hoped that this burden will not exceed by a heavy amount the available margin of income, and if it should, that the substantial reserve available should be sufficient to meet any probable contingency.

In conclusion, we believe that in spite of many difficulties, physical, economic, and now political, we have made, and are making, wise and adequate provision for a trade and commerce which is certain to expand and the limits of which it is difficult to foresee.

DISCUSSION.

THE CHAIRMAN said that the lecturer had dealt with his subject from the very beginning right up to modern times. He had gone back to a period which he (the Chairman) remembered perfectly well, when there had been no jetties in Calcutta, and when all the ships had been sailing ships—and very beautiful they had been. He also remembered perfectly well when he had been in a firm which did shipping business, and how they used to have to go out into the river in a small boat in order to negotiate with lighters so as to get them to go alongside the ships—and it had been a very arduous and slow task. Some time after that, three jetties had been built, and, later on still, two or three more had been added. Eventually the lack of accommodation had made itself so pronounced that a committee had been appointed to enquire into the question of the provision of docks. At first the idea of providing Calcutta with docks had met with great opposition. It had been said that they were unnecessary, that the money would not be forthcoming, and so on. However, wiser counsels had prevailed, and docks had been built. At about the time when the port of Chittagong had been opened, which had taken away some of the traffic and had thus relieved the situation, he recollected that in 1913, when Sir Austen Chamberlain had presided over a Currency Committee he (the Chairman) had appeared as a witness before that Committee, and at the end of his evidence Sir Austen Chamberlain had asked him if he had any general observations to offer about railways and port traffic, and he had then given some facts about railways and had told Sir Austen that he considered that the provision made for the port traffic of Calcutta would very soon prove to be too small for the requirements, and that it would be quite reasonable to suppose that within a very short time the capacity of the docks would have to be doubled. It was now seen that the docks were going to be doubled. It was also to be noted that docks at various other points were going to be opened. Yet, with all those ports, he ventured to say that the time would come when it would be found that they would not be

sufficient as the trade of India developed. The lecturer himself had given figures to the effect that during the five years ending March, 1928, there had been an increase of 38 per cent. in gross tonnage of vessels entering the port of Calcutta, and an increase of 46 per cent. of goods handled during that period. Those were very large figures. If one looked at the most recent figures, one would see that for the twelve months ending 31st March last, as against the previous year, there had been an increase of 19 crores, or 6 per cent. in exports, and 8 per cent. in imports. If one took a number of years—say 12 or 15—and multiplied those figures accordingly, one would see that it looked as if something colossal would require to be done to meet the exigencies of the case, and personally he thought it might be found that the docks, when they were completed, would be still too small for the trade of Calcutta. In calculating what the increase would be, coal was no factor at all at the present moment, but many present would have noticed how the pendulum swung; and he thought it was reasonable to suppose that coal, being one of the chief commodities in India, would still be exported in very large quantities in time to come.

The only other thing he desired to do was to congratulate those who had had been responsible for the finances in Calcutta of the Port Trust. He saw, in looking up the figures, that, with the exception of one loan, they had done as well in Calcutta as they in the Port of London had done in London. Only in the case of a single loan had they paid such a high figure as 7 per cent.—which, after all, was not considered a very high figure in India. Now they had come back to the same figure as the last issue of Port of London Stock, namely, 5 per cent.

MR. C. E. BUCKLAND, C.I.E., said that, as a former Chairman of the Calcutta Port Trust, he had attended that afternoon to hear from the lecturer what had been done since he himself left India. The account which the lecturer had given of the development of the port was intensely interesting, and showed how large a field there had been and was for development, and how well the Port Trust were fulfilling their duties. Speaking as an old official, he had hoped to have heard something from the lecturer as to the present administration and constitution of the Port Trust, and what its relations were with the Government and with the authorities. The lecture had shown how the Government had been doing its very best for many years to foster and encourage, and to give every facility to, trade that it possibly could. It had done that, in one respect, by making over the administration of the port to a body of more or less independent gentlemen, and now they had put the Trust under a non-official Chairman. He did not suppose there was anybody in the room who had the faintest idea as to who had been the real author of the Port Trust in Calcutta, but as a fact it had been Sir William Grey who was Lieutenant-Governor from 1867 to 1871. From the time the Port Trust had come into being, in 1870, it had generally been under the immediate supervision of a highly placed member of the Civil Service. Many eminent names—among them Mr. Vernon Scholch, Mr. C. T. Buckland, Mr. Reynolds, Sir C. Stevens—would come to one's mind, of men who had headed the Port Trust, and who had done all they possibly could to develop the port and docks. For many years the chief spirit in that work had been Mr. Duff Bruce, who had been for seventeen years Vice-Chairman of the Trust, and to whom the development of the port and of the Trust was more due perhaps than anybody else. We might also mention the late Vice-Chairman, Sir F. Dumayne, and the Engineer, Mr. F. Palmer. Matters had changed considerably since those times. Why it had come to pass that the Board of Revenue no longer had anything to do with it, and

why a non-official Chairman was now in office, it was not in his power to say, but he had no doubt that the work was still being well done, and was a very good illustration of what could be carried out by co-operation between officials and non-officials. Government had shown, very rightly, great intelligence in allowing men who were most interested and capable to do their own job. The meetings which used to be held weekly in the Port Trust chamber, consisting of about a dozen leading merchants, shipping agents, and people who were thoroughly interested in the question, had always been of a most agreeable kind. All had been most anxious to develop the port and to do what they could to facilitate the trade and to improve it in every possible direction. He was glad to see that that spirit was still maintained. Although the names of the present Commissioners were not known to him, except that of the Chairman, he felt sure from the paper read to them, that the work was being thoroughly well done, and that the port had an immense future before it. Everyone knew that Calcutta was founded upon Trade from the time of Job Charnock in 1690, and everyone knew how enormously it had expanded since the *Pax Britannica* had been thoroughly established in the country. No one could forecast the future, but humanly speaking, there was no reason to suppose that the Port Trust would not go on developing and do all that was required of it. Nothing but a natural convulsion could drive Trade away from Calcutta, and it was impossible to suppose that such a convulsion of Nature would occur, or that Calcutta would be swept away by a tidal wave, or that the waters of the Bhagirathi and the Hoogly would go in another direction. He was certain that the Port Commissioners would provide the very best facilities for the enormously expanding trade which was now coming, and would in the future come, down from Upper and Eastern Bengal, from Assam and from the whole country.

MR. C. H. BOMPAS, C.S.I. (Formerly Chairman, Calcutta Improvement Trust), congratulated the lecturer on the way he had described the development of the port of Calcutta. Things moved so quickly nowadays that it required a lecture like that which had been just delivered to make people realise how rapidly they really had moved. The developments described in the lecture had all occurred since he had first gone to Calcutta—and he was not yet quite a fossil! When he had gone to Calcutta the docks had then only been under discussion—the Kidderpore docks. Both the imports and the exports were then dealt with in the river, opposite Calcutta proper. It was important to remember that the docks, beginning with the new Kidderpore docks and other extensions, as shown on the map exhibited on the wall, were really away from Calcutta. There were no signs of Calcutta on that map. There were two square miles of *maidan*, of open plain, round the fort, between mercantile Calcutta and the docks. That was a side of the question which interested him more particularly and which he thought might form the subject of an interesting additional paper by Mr. Stuart Williams. It was a remarkable thing that such a sudden change had been made in the traffic routine of a great port and city like Calcutta. From the time of the East India Company onwards—from the time of the foundation of Calcutta—imports and exports had been landed at a certain point on the river. Houses had grown up, and mercantile practices had developed on that basis. Then the traffic had outgrown those facilities, and a new harbour was made three miles downstream. That meant great changes in warehousing and traffic arrangements, but naturally they would not take place very quickly. Trade was conservative. There was nobody to make arrangements. He would be interested to know how far the merchants, especially the Indian

merchants, of Calcutta had succeeded in accommodating themselves to the new conditions. It was only fifteen years ago since the Calcutta Improvement Trust had cleared away an area in the very centre of Calcutta, which area had been occupied by the hide trade. There was a very extensive export trade in hides at the port of Calcutta, and up till that time all the hides exported from Calcutta had been carted into the centre of Calcutta, sorted, stored, sold, and then carted out again, on land, which, when cleared and developed, had sold for £50,000 an acre—which showed how uneconomical had been the use to which that land had been put. Anyone who knew the Bazaar district of central Calcutta knew that there was still a vast amount of merchandise being taken into the middle of Calcutta and taken out again which, as far as he was aware, was to a very great extent unnecessary, and was merely a legacy of the time when that spot had been the centre of the Calcutta export and import trade.

There was another question of a somewhat similar nature connected with that, namely, that when one got enormous docks, as shown on the lecturer's plans, it was natural to suppose that a town would grow up around them in order to accommodate all the labour connected with the docks, warehouses, offices and everything connected with trade. The new docks were situated more or less in a swamp. There was not only no drainage, but no probability of drainage. If the increased water supply system for Calcutta had now been completed, he supposed the Calcutta Municipality would supply them with a little spare water. That was a question of a very serious nature as regarded the welfare of a great port, and he was afraid it was one in regard to which there was no authority qualified to tackle it. The Howrah district had not yet been dealt with. That was a part of Calcutta with a population of 250,000 people. It had no drainage system, and the sanitary conditions were appalling. Everybody was so occupied now with trying to kill or cure the diarrhal system that he supposed it was even less likely than it had been in the past that those important questions would be taken in hand. It was a matter with which the lecturer was not directly concerned, but indirectly it very much affected the welfare of the port, and he would like to hear from the lecturer something of what was being done in that respect.

SIR ALEXANDER R. MURRAY, C.B.E. (formerly President, Bengal Chamber of Commerce), said the lecturer had made some remarks regarding the original site of Calcutta. In his own reading of the history of the district, it appeared to him that Charnock came to the east side of the river in order to avoid the attacks which were being made on the trading ports on the other side by the Mahrattas and others. With the river lying between, Charnock felt that he was much safer, and that was probably one of the prime considerations which influenced him in coming to the left bank of the river. The fact that all the other trade ports previously occupied by the Portuguese, the Danes and the Dutch had all "gone West" showed that Charnock was justified in his action.

He had been interested in what the lecturer had said regarding the establishment of the Port Trust in 1870. As a matter of fact, in those days the Port Trust had had only about £100,000 worth of property altogether; that was what the Trust had taken over. To-day they had assets amounting to over £20,000,000, which showed what great development had taken place in the short space of fifty-eight years. Very few realised that in the port of Calcutta there were handled, at the docks, in the jetties and in the stream, imports and exports amounting to 10,000,000 tons per annum. Of those 10,000,000 tons $2\frac{1}{2}$ million tons were coal, leaving $7\frac{1}{2}$ millions for food and merchandise. Of those $7\frac{1}{2}$ million tons practically 4 million

tons were still being handled in the stream ; that was to say, they did not go on to the jetties, nor were they handled in the dock sheds. He could well remember the committee which sat in 1901, and again in 1913-1914, and the continuous worries they used to have in the old days about delays to boats and merchandise owing to congestion, and how they used to curse that 60-ft. lock that was the main entrance and exit to the docks. Everybody would be very pleased when the new 80-ft. lock would be opened. The lecturer had referred to the assistance he had received from the commercial community in Calcutta, and from banks and others, in connection with the floating of loans. Speaking as a commercial man, he could say that the officers of the Port Trust themselves had had a good deal to do with the success which had attended the raising of those loans. In the Chairman, the Deputy-Chairman, the Chief Accountant, the Traffic Manager of the railways and the Chief Engineer, the Trust had a body of men of whom Calcutta could be extremely proud.

MR. J. ANGUS, M.Inst.C.E. (Consulting Engineer to the Calcutta Port Commissioners), said there was very little left for him to say, as so much had been already said, and said so well ; but he would be failing in his opportunity if he did not pay his acknowledgements to the lecturer for the very excellent paper he had presented that afternoon. The only complaint he had to make was that the paper reminded him that he was forty years older than he was when he first started with the Port Commissioners. He had been connected with the Kidderpore docks under his old chief, Duff Bruce, and it had been interesting to him to hear the opinions which had been expressed as to the great value of Duff Bruce's work. Reference had been made to the objections which had been advanced against the construction of the docks. It had been said first of all that the docks were not wanted and that docks, in any case, if they were wanted, could not be built on the soil of Calcutta, and that even if they could be built on the soil of Calcutta, Kidderpore was not the right place for them. Duff Bruce, however, had persisted, and he was glad to say that he had been found right. Duff Bruce had built his docks, and had built them at a comparatively cheap price, and they had turned out a great success. Personally, he remembered very well that after the docks had been completed they had not been sufficiently occupied for some considerable time. That was a condition of affairs which so far as his own experience went, obtained in practically every new dock works or extension of docks. Reference had been made to the difficulties entailed in moving one's business premises, and everything connected therewith, from one point to another. Perhaps a good illustration of what had happened in the case of Kidderpore docks, which had been built three miles below the city, was the case of Tilbury Docks, with which he had been also connected. Those docks were built much further from the City of London than was Kidderpore from Calcutta. Tilbury docks had been very inadequately used for some years after they had been built. In due time it had been discovered that those excellent docks, with all their splendid facilities, were in the right place, and since then they had more than doubled, and year by year extensions were going on. Therefore, dock authorities had to look well ahead and be prepared to take their courage in their hands and decide when was the time to build and where. He thought it might be taken as an accepted fact that docks or jetties when they were built could not be expected to be filled immediately. The approaching completion of King George's Dock would form a very fitting record of Mr. Stuart Williams' successful administration.

MR. STUART-WILLIAMS, in reply, said in reference to the Chairman's remarks regarding finance, the Calcutta Port Trust did have to pay 7 per cent. for a loan in 1921, but they hoped to repay that loan in 1931. They had taken the precaution to stipulate that it could be repaid in ten years. Mr. Buckland had asked for some information as to the present constitution. The Trust had developed a good deal in numbers. The Board was now comprised of six representatives from the Bengal Chamber of Commerce; four from Indian Chambers of Commerce; three railway managers; one representative of the Corporation of Calcutta; one representative of the Royal Indian Marine; one representative from the Trades Association, and the Collector of Customs. Mr. Buckland had paid a tribute to the Government Chairmen of the past, and personally he would like to endorse that tribute. He himself had been closely associated with one Government Chairman, Sir Charles Stevenson-Moore, from about 1914 to 1921, when the change in the constitution had come about, and it would be extremely remiss on his part if he did not pay a special personal tribute to the support, advice and criticism which he had always received from Sir Charles.

With reference to Mr. Bompas' remarks regarding traffic conditions in Calcutta, Mr. Bompas had put his finger with unerring skill on to two very difficult points. One was the fact that the new dock area, as he had said, was divided from the city by several square miles of the Calcutta *Maidan*, and any traffic carried by cart or lorry from the new dock area had to cross or else to go round the *Maidan*, which was so very important an amenity in Calcutta life. That difficulty could not be met altogether, but in order to meet it as far as possible the Trust were encouraging traders and warehousemen by every possible means to develop in those areas which the Trust had available. They were given low rates and offered a special bonus of half rates for the first year during which the buildings were being put up. The railway charges had also been recently reduced, and it was hoped to give other facilities in the future. That policy was having some effect, though not as much as he should like to see, and it was significant that the value of the land in the Burra Bazaar, which was the most densely populated and most utilised portion of Calcutta, was, he believed, beginning to go down. With regard to the provision of municipal amenities in that area, Mr. Bompas had referred to a very difficult position. The Corporation of Calcutta was now almost entirely divorced from Government control. The only way which Government had was in the approval of their Budget and in the approval of loans; otherwise the Corporation was absolutely autonomous. Presumably it was doing its best, but its schemes took a long time to draw up, and took longer to mature. As an instance he might quote its new water supply scheme. That had been commenced in 1922, and, according to schedule, should have been finished in 1925, but it was not yet half finished in 1928. The whole of the drainage arrangements were in a very difficult and unsatisfactory condition. It was obvious that the method of drainage which had been pursued for the last forty years was no longer adequate, and no feasible programme for the future had yet been drawn up. The whole position, therefore, was extraordinarily difficult. Mr. Bompas had said that he (the lecturer) only had an indirect interest in such matters. As a matter of fact, he had been a Municipal Commissioner for three or four years and he was doing his little best against very considerable difficulties.

With regard to Sir Alexander Murray's remarks about the 4,000,000 tons of traffic which was dealt with in the stream, he would like to make one point clear. A lot of that traffic was salt, and a good deal more was petroleum and petrol. The salt had to be dealt with in the stream because it went across the river to Govern-

ment warehouses on the other side. The oil had to be described as stream traffic because it went over the wharves into the separate depot at Budge, which was said to be one of the best petroleum depots in the world. Jute and gunnies were also spoken of as stream traffic, and the greater part of it was ; that was to say, it did not pass over the wharves but it went to ships lying in the stream or in the Docks by means of small cargo boats, and all such traffic was called stream shipment.

Mr. Angus had referred to his own long and honourable connection with the port of Calcutta, and paid, as had Mr. Buckland, a well-deserved tribute to Mr. Duff Bruce. Sir Alexander Murray had also paid a tribute to his (the lecturer's) present colleagues. Nobody endorsed those tributes more sincerely and heartily than he himself did. In his view the work of his predecessors had not been appreciated so highly as it ought to have been. Personally he did feel very grateful for any tribute which was made by leading commercial men to his colleagues, who had done, and were doing, their very best for the welfare of the commercial community of Calcutta and the prosperity of the port.

A hearty vote of thanks to the lecturer for his interesting lecture concluded the meeting.

NOTES ON BOOKS.

ART IN THE LIFE OF MANKIND. By A. W. Seaby. London : B. T. Batsford, Ltd.
Vol. I. A general view of art. Vol. II. Art in ancient times. 5s. each.

The part played by art in the life of mankind to-day is not a very large one. The leading roles are taken by invention and commercial technique. If the hero of " *Le Rouge et le Noir* " were to be reincarnated to-day at an age of, say, twenty, he would turn neither priest nor soldier, and he would leave the arts alone. He would go in for salesmanship. There has been no period since the Renaissance when he might have been tempted to train as a scholar or an artist.

Nevertheless, with a slackening of industrial expansion, there has come an increase of interest in the arts. Of this tendency Professor Seaby's books are at once a manifestation and an encouragement. Only a small proportion of civilised humanity attempts to create works of art, but a quite large proportion is beginning to like examining and reading about works of art. A little learning here is a dangerous thing, as always, but not dangerous to life and limb, as are certain of the other preoccupations of our contemporaries.

And so good luck to such works as Professor Seaby's, which turn attention into the most delightful and humane of all channels. His first two volumes of " *Art in the life of Mankind* " are, but for one point, excellent. That one point is rather puzzling to the present reviewer. Why does Professor Seaby suggest in his Introduction that he adheres to an impossible and absurd theory about the " *meaning* " or function of art ? It seems clear from what follows that he is not really blind to the truth. He says that art " *calls to the good in us.* " He says that the study of art " *may stir us to resolutions and deeds of which otherwise we might have deemed ourselves incapable.* " He holds up a picture by W. H. Hunt as both expressing and inspiring the viewer with the qualities of " *truth, courage, tenacity and tenderness.* "

The whole paragraph of which the above are extracts is appalling. Why was it

written? To conciliate—with the best of motives—whom? To make the series palatable to pastors and masters and all others whose professions demand that they should be truthful, courageous, tenacious and tender, and able to form the young in their likeness?

It is positively important that at this stage of civilisation aesthetics and morals should not be confused. Art is not, has never been, and will never be a sort of more sedentary expression of the spirit which infuses the Boy Scout movement. Whatever teachers may be, artists are not as a race more courageous, tenacious, etc., than shoeblacks or bonesetters, and about as much concerned as these with the conversion of humanity. Artists live *sub specie aeternitatis*; they live, therefore, not for the morrow, since for them there is no morrow and there has been no yesterday.

The chapters immediately following the introduction are as warrantable in their generalisations as that is unwarrantable. A service rifle is perhaps not as exquisite, aesthetically, as Professor Seaby suggests: but how true the remarks on the same page about manufacturers trading on "a supposed love of novelty."

On the distinction between natural beauty and aesthetic beauty, or significance, or rightness, Professor Seaby is fairly explicit. On proportion he has much to say that is worth reading; lack of a sense of proportion is so readily excused by modern people in one another. (See Tolstoy on the building of the Eiffel Tower.) It is quite possible that "learning to draw in right proportion may be a step towards seeing life in right proportion, ignoring the little things, to fasten attention on the big facts, to take long views." It is quite possible that proportion, in all its various aspects, contains the secret of happiness for the individual and for the community: Clive Bell quotes someone as saying, in answer to the question: What is Proportion?—God.

Having dealt with rhythm, convention and colour the author passes on to houses, decoration and pictures. At the end of Volume I he touches on a matter of the highest relevance. "Why," he asks, "has art not been recognised as a study of academic status, and why are degrees in fine art not commonly conferred by universities in Britain?" Why indeed? In German they have a word to describe the graduate in fine art who has continued his studies and whose aim it is to forward the cultivation of taste, the business of collecting and preserving works of art, etc; the word is *Kunstforscher*. The *Kunstforscher* has his niche in the social and academic scheme; it is hard to understand how a society which does not provide such a niche can fancy itself civilised.

In Volume II Professor Seaby begins his survey of the "achievements" of art from the earliest times. His historical sketches are for the most part thoroughly readable. They are based on the rapidly increasing body of knowledge accumulated by the archaeologists of all nationalities who have been at work during the last century. A few slips in grammar will no doubt be corrected in a second printing; for instance at the bottom of page 70 occurs the sentence: "Karnak takes hours even to traverse its mazes of courts and apartments."

How the study of pitched battles, which can only be illustrated by little diagrams of rectangular blobs and dotted lines, has ever competed with the study of art in all its forms, is not easy to understand. Yet Professor Seaby is, practically, a pioneer. The *Ars Una* series, edited by Professor Reinach, which contained a number of admirable treatises, was more elaborate and expensive. Various other foreign competitors exist. None of them render Professor Seaby's work superfluous, though it would be too much to say that the books he has written will not be superseded. He has a very easy—that is to say, skilled—manner of

welding together history, criticism and psychology, and the plan of the series seems to be very good. He has one of the best of popular styles.

The books themselves are most agreeable to the eye and hand ; their size, the texture and design of the covers, the type and the indices are all most satisfactory. I do not know why Volume I is red and Volume II blue, or whether the remaining Volumes are going to be green, orange, yellow and white (if so why was Vol. I not violet ?) ; I should have thought that a series were best kept in the same colour.

LYSIPPOS. By Franklin P. Johnson, Ph.D. Duke University Press. 37s. 6d.

Pliny once made a remark that is alleged to be a quotation from Lysippos himself, to the effect that while former sculptors had represented men as they were, he represented them as they appeared to be. Mr. Johnson joins in the nice controversy which arose long ago from these words. For "appeared" should Pliny have written "ought" ? No ; we must leave Polykleitos the title of idealist, and take it that Lysippos referred to the animated expressions and gestures which he had the genius to communicate to figures of marble and bronze.

It is well known that Lysippos revised the Canon of Polykleitos, somewhat increasing the length of the body in relation to the size of the head ; compare the Vatican copy of his Apoxyomenos with the Naples copy of the Doryphoros by the older master. But Lysippos did more, he attained a certain refinement which has made critics ask whether his art was a culminating point or the beginning of a decline. Mr. Johnson takes the latter view, but adds that the position thus assigned to him is a very high one : "the succeeding epoch was formed by him more than by any other artist."

Lysippos declared that his only masters were Nature and the Doryphoros. However, Mr. Johnson considers that the strongest influence to be detected in his work was that of Skopas, and, indeed, a number of statues have been equally credibly ascribed to both sculptors.

The great merit of Lysippos is that he weaned sculpture in the round from bas-relief finally—not that later artists of repute have always managed to produce statues which bear scrutiny from more than one angle. What Lysippos did was to define sculpture, to show that its limits were wider than had hitherto been supposed. He balanced his figures in new ways, made them strike new attitudes, disposed their limbs with a new grace, gave them a new vitality. On the other hand, Mr. Johnson observes that "we find no evidence anywhere of lofty idealism or of profound spiritual expression in his work," and is therefore inclined to believe that the alluring lady known as Aphrodite de' Medici is in fact a replica of an original by Lysippos. A pleasant sensuousness is one of his characteristics.

• Born in Sikyon, Lysippos became court sculptor to Alexander the Great. He was an admired portraitist, versatile also in his power of representing animals : dogs, horses, lions. It was difficult or impossible to copy some of his more complex and colossal groups, so that we have only literary evidence for their existence and worth. In the present book Mr. Johnson has carefully examined the claims of works attributed with more or less plausibility to the master, and has given at the same time a general survey of Greek sculpture in the fifth and fourth centuries. He makes no contribution to the subject apart from such fruits as his discussion of the views of the different authorities may bear ; but this discussion is conducted with a lucidity which more than justifies the labour he has expended.

JOURNAL OF THE ROYAL SOCIETY OF ARTS

No. 3949.

VOL. LXXVI.

FRIDAY, JULY 27th, 1928.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

AWARD OF THOMAS GRAY MEMORIAL PRIZE FOR NAVIGATION.

The Thomas Gray Trust was recently established under the will of the late Thomas Gray in memory of his father, the late Thomas Gray, C.B., formerly Assistant Secretary to the Board of Trade, Marine Department, for "the Advancement of the Science of Navigation and the Educational Interests of the British Mercantile Marine." The Council of the Royal Society of Arts, which administers the Trust, decided to offer a prize for Navigation of the value of £30 for competition between selected candidates from the three principal training establishments for boys intending to become officers in the Mercantile Marine, viz., the Nautical College, Pangbourne, the Training Ship, "Worcester," off Greenhithe, and the Training Ship, "Conway," at Birkenhead. The prize, which has been offered this year for the first time, has been awarded, upon the result of an Examination recently held, to CADET-CAPTAIN JOHN HERBERT CHALK, of the Nautical College, Pangbourne, an "Honourable Mention" being accorded to H. H. G. TRACY (Nautical College, Pangbourne), P. BEEHAM (T.S. "Worcester"), and C. D. CALLIEU (T.S. "Worcester"). The prize was presented at the Nautical College, Pangbourne, on Tuesday, July 24th, by CAPTAIN SIR ARTHUR CLARKE, K.B.E., Member of the Council of the Society, and Elder Brother of Trinity House. Members of the Consultative Committee of the College, on which the Admiralty and other bodies are represented, also attended the presentation.

COMPETITION OF INDUSTRIAL DESIGNS.

A selection of the Designs received in the above Competition for Prizes and Scholarships offered by the Society, the Empire Marketing Board and well-known manufacturers will be exhibited, by kind permission of the Board

of Governors, in the Exhibition Pavilion of the Imperial Institute, South Kensington, from the 4th of August to the 1st of September next, every weekday from 10 a.m. to 5 p.m. (Sundays 2.30 to 6 p.m.)

The Exhibition is open free of charge; no tickets are required. It will include Designs for Architectural Decoration (Wrought Iron Canopy for a Theatre, a Petrol-Filling Station, a Decorative Fountain, Bathroom, &c.); Silver Cup for the Swiney Prize for Jurisprudence; Textiles (Carpets, Lace, Embroidery, Silk Fabrics, Cretonnes, Printed Furnishings, and Printed and Woven Dress Goods); Wallpaper; Furniture (including a Cabinet for a Wireless Receiving Set); Panels for Baby Carriages; Printing and Book Production; Pottery and Glass; as well as designs for Posters, Showcards, Christmas Cards, Calendars, Bookmarks and a Booklet Cover.

Several other important firms, as well as the Corporation of a well-known seaside resort, have expressed a wish to offer Prizes for Designs in connexion with the 1929 Competition.

A Bureau of Information has been established at the Royal Society of Arts in connexion with the Competition, for the registration of the names and addresses of exhibitors who desire to obtain employment as designers. These lists are at the service of manufacturers in search of designers.

A report on the competition, including full lists of awards, will be published in the *Journal* at an early date.

PROCEEDINGS OF THE SOCIETY.

THIRTEENTH ORDINARY MEETING.

WEDNESDAY, 22ND FEBRUARY, 1928.

LIEUT.-COL. SIR ARNOLD T. WILSON, K.C.I.E., C.S.I., C.M.G., D.S.O.,
in the Chair.

THE CHAIRMAN, in introducing the lecturer, said that the archæological experience of Dr. Hall, both theoretical and practical, was unrivalled alike in this country and in Europe. His knowledge extended to Egypt and to Crete, to Palestine and to 'Iraq. He was actively engaged a few years ago in actual excavations in 'Iraq. His services, like those of other archæologists, were commandeered by His Majesty's Government during the war, when they were as notable as they were valuable.

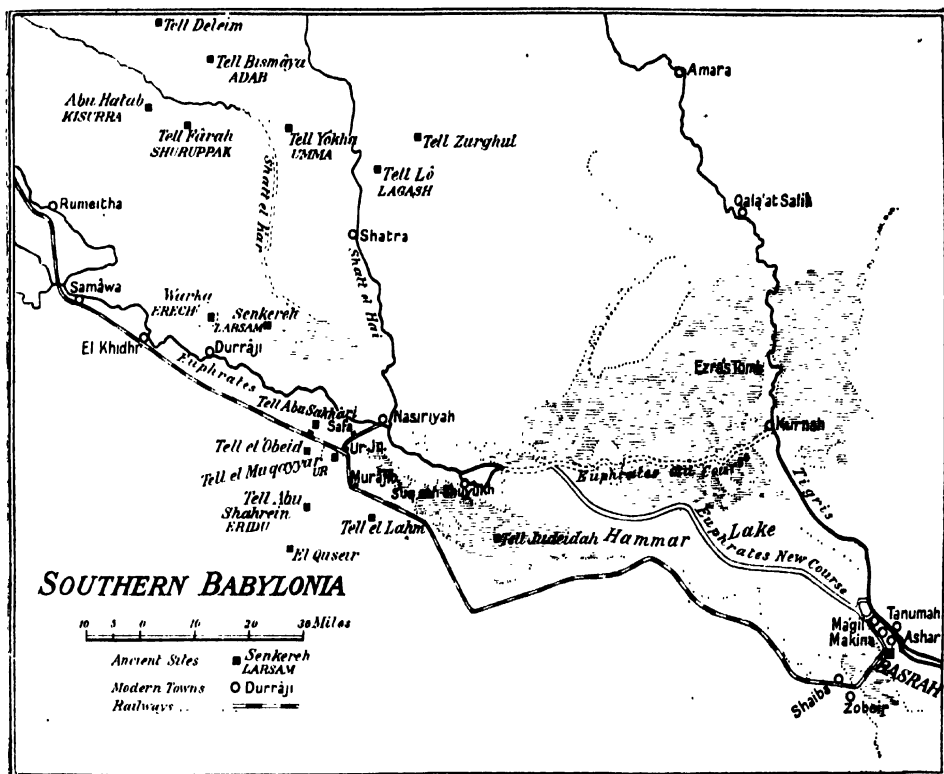
The following paper was then read:—

THE EXCAVATIONS AT UR (1919 TO 1926).

By H. R. HALL, D.LITT., F.B.A., F.S.A.

The excavations of 1919 at Ur of the Chaldees were carried out under my direction at the expense of the Trustees of the British Museum, the total

outlay, owing to help given by the civil and military authorities in 'Iraq, being only £600 odd. Expenses have gone up since then, and it is now impossible to carry on excavations for anything like so small a sum. From £3,000 to £4,000 at least is wanted for a good season's work, if it is to be carried out really efficiently.



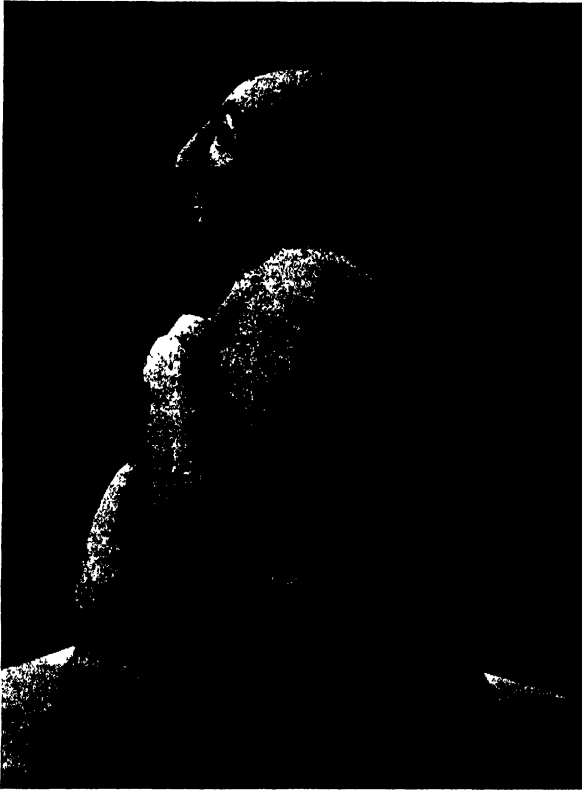
Map of Southern Babylonia.*

Ur is a site long associated with the British Museum. In Crimean days, in the enthusiasm aroused by the decipherment of the cuneiform script by Rawlinson, it was attacked on behalf, first of private subscribers, then of the Museum Trustees, by Mr. J. E. Taylor, H.B.M.'s Consul at Basrah; and there are many relics of his diggings in the British Museum. In 1918, when our military occupation of 'Iraq afforded the opportunity, the Director of the British Museum, Sir Frederic Kenyon, decided that the time had come for renewed excavations in Babylonia, and Capt. R. Campbell Thompson, late of the British Museum, then in 'Iraq as an Intelligence Officer, was commissioned to begin the work. He first of all investigated Ur and made one or two trial soundings there, but after a week's work went on elsewhere; and

* Reproduced by kind permission of the Society of Antiquaries.

next year I began the first systematic excavation at Ur, discovering the palace-building É-kharsag, built by the king Shulgi (this identification of mine (*), at first doubted by Mr. Woolley (†), is now accepted by him) (‡) within the temple-area, part of the temenos-wall of the temple-area, part of the S.E. face of the *ziggurat* or temple-tower, and various tombs, *etc.* I worked continuously for over three months at Ur, so that the excavations there amounted to a good deal more than a mere preliminary investigation.

The chief results, however, were obtained at the site of al-'Ubaid, a small *tell* in the desert, four miles from Ur itself, which I discovered in April, 1919. Here I found the remains of a small temple of the goddess Ninkhursag or Damkina, which I assigned to the early Sumerian period, *c.* 3000 B.C., a diagnosis since entirely confirmed by Mr. Woolley's discovery of the foundation tablet of A-anni-padda, a king of the First Dynasty of Ur (*c.* 3100-2900 B.C.).



Stone figure of Kur-Lil (?) doorkeeper of the Temple at Erech, Al-'Ubaid: about 3,000 B.C. (Hall, 1919).

* *Journal of Egyptian Archaeology*, 1923 (ix), p. 183.

† *Antiquaries Journal*, Oct. 1923 (vol. iii), p. 317.

‡ *Ibid.*, Oct. 1926 (vol. vi), p. 383.



The Im-dugud relief at al-'Ubaid, as found, 1919. (Hall).

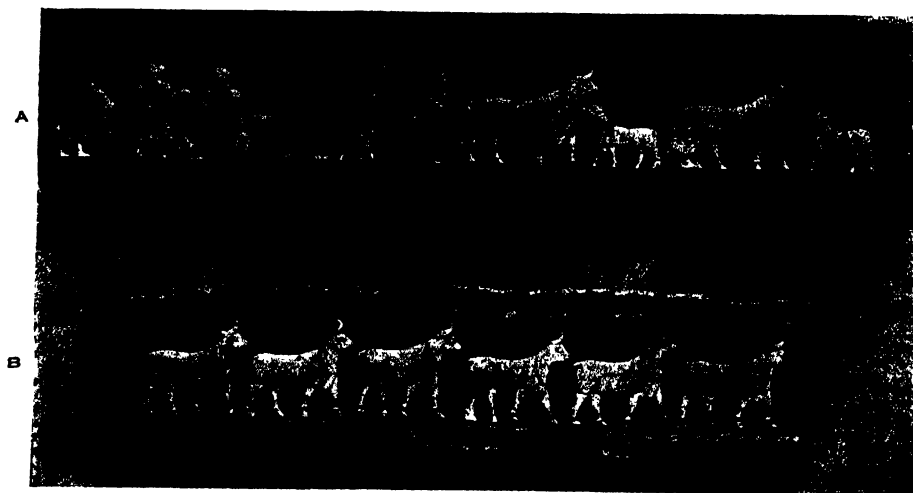
who erected the building on the site of an ancient cemetery, many relics of which, consisting chiefly of prehistoric stone implements and painted pottery fragments, were lying on the surface of the desert. The trophies of this work in 1919, consisting of the stone figure of the priestly official Kur-lil, the great copper relief of the mythical lion-headed eagle Im-dugud grasping two stags by their tails, and the bitumen heads of lions covered with copper, are all now in the British Museum, thanks to the active sympathy with the work of Lt.-Col. Sir Arnold Wilson, then Acting Civil Commissioner. The work of conserving and packing the Im-dugud relief, and bringing it to England, was one of great difficulty, and it is a matter of congratulation that the relief, as now exhibited in the British Museum, has needed comparatively little restoration.

After my departure, various reasons forbade the resumption of the work till the year 1922, when the Director of the British Museum was able to take it up again in conjunction with the Museum of the University of Pennsylvania, at Philadelphia. The two Museums have shared thenceforth in the expense of the dig on a principle of absolute parity; and after the Museum of Baghdad has taken its legal toll of the finds, the remainder is divided equally between the two museums. The director of the work since the resumption has been Mr. C. L. Woolley.

After a preliminary season at Ur, Mr. Woolley completed the excavation at al-'Ubaid, which I had had to leave half-finished, as I had expected to be able to complete it in 1920. The results of the completed work were the accurate planning of the site and the discovery of the copper figures of bulls, the frieze of the milking-scene, and other objects, which have been published in the joint work by Mr. Woolley and myself, *al-'Ubaid*, the first volume of



Lion-head of bitumen covered with copper, al-'Ubaid. (Hall, 1919).



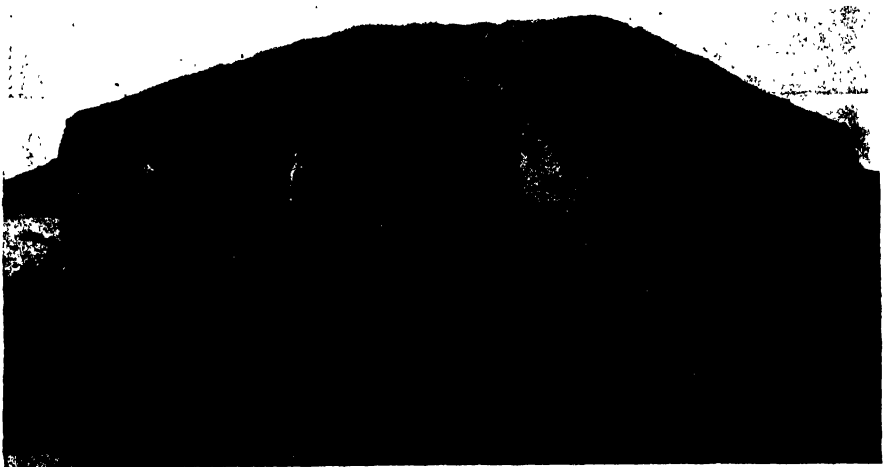
(a) Inlay Frieze with limestone figures: milking scene. (b) Inlay Frieze with shell figures: procession of Bulls.* (Woolley).

* Reproduced by kind permission of the Society of Antiquaries.

the publications of the two museums on the excavations, which appeared in 1927. To Mr. C. J. Gadd, my assistant in the Department of Egyptian and Assyrian Antiquities, is due the translation in this book of the early cuneiform texts discovered, which have confirmed the original dating of the building and its antiquities in 1919, based on archæological data.

Mr. Woolley had during his work the advantage of the assistance of first-rate experts in the reading of cuneiform, an invaluable help to the archæologist pure and simple ; as unless one has someone to explain the meaning of the inscriptions one discovers, one is to some extent working in the dark. In his first season he had with him Mr. Sidney Smith, of the British Museum ; then Mr. Gadd ; then the Rev. Dr. Legrain, of Philadelphia ; latterly the Rev. E. Burrows, S.J.

His architectural expert was the well-known archæological architect, the late Mr. F. G. Newton, whose untimely death in Egypt we all deplore. To Mr. Newton was due the admirable restoration of the temple-tower of Ur, rendered possible by Mr. Woolley's clearance of the whole building. From this work we first learnt the real arrangements of a Babylonian *ziggurat*, with its triple stairway of ascent on one face. It is not of course to be supposed that all *ziggurats* were ascended in this way ; but this was the first of which the arrangement was unequivocally restorable. Latterly Mr. Woolley has



The Ziggurat, N.E. face.* (Woolley and Newton).

* Reproduced by kind permission of the Society of Antiquaries.

had with him Mr. A. S. Whitburn, as his architectural assistant, and Mr. M. E. Mallowan as his archæological helper.

Mr. Woolley during his first season's work has dug out all or nearly all of the buildings, of all dates from the Third Dynasty of Ur to the Persian period, within the temenos of the Moon-god. Proofs were obtained of the use of both the column and the arch as early as 3000 B.C. The streets of part of the ancient town, with their houses, have been excavated, with the result that the Baby-



E-Dublal-Mah seen from the street running past the door of the Nin-Gal temple.* (Woolley).

onian house of 2000 B.C. appears to have been very like a house of modern Baghdad. But the most startling result of Mr. Woolley's digging has been the discovery of the First Dynasty cemetery, of 3000 B.C. and before, containing the burials of princes and princesses or priestesses of the older Sumerian period, with treasures of gold that approach, if they do not surpass, those of Mycenae, and in interest are hardly inferior to the relics of Tut'ankhamen. The description of the newer and more important discoveries of 1927-28 must be left to the excavator himself. The wonderful gold dagger and its open-work sheath, the gold vanity-case or *étui* with its tweezers, ear-scoop, and head-scratcher, and its spiral decoration (the oldest known), and above all, the

* Reproduced by kind permission of the Society of Antiquaries.



The Golden Dagger of Mes-kalam-dug in its sheath. (Woolley, 1927).

beautiful little silver lamp with its fluting and incised decoration, the highly developed jewellery, and the electrum lance-head and adze-axe with its socket—so far ahead of the contemporaneous Egyptian work of the First Dynasty at Abydos, as to make very credible the idea that the Sumerian culture was older than that of Egypt and certainly the more highly-developed of the two c. 3000 B.C.—have been surpassed this year by an extraordinary treasure of gold vases, and such wonderful objects as the gold “wig-helm” of the prince Meskalamdug, and the flower head-dress of the priestess or princess Shubad. The description of the graves of Meskalamdug and Shubad, with the bodies of their massacred slaves, the dead soldiers on guard outside the tomb of Shubad, the chariots drawn by asses and cattle, the harper and his harp, will be published by Mr. Woolley in the *Antiquaries Journal* in which



The golden "Wig-helm" of Mes-kalam-dug. (Woolley, 1928).

he has regularly since 1922 published his preliminary illustrated report on each season's work.

This is the most important archæological excavation in the world at the moment, and considerable expenditure is necessary for its efficient prosecution. Contributions from any persons interested in archæological work will be welcomed by the Director of the British Museum.

DISCUSSION.

SIR MARTIN CONWAY, M.P., in opening the discussion, said that those who were no longer young, and who had lived through the period of excavation which might be said to have begun with Schliemann, and which had gone on increasing in activity ever since, would have been almost accustomed to expect every few years that the veil which hid some great bygone civilisation would be lifted by enterprising excavators. One civilisation of the past after another which had been almost completely forgotten had been rediscovered, re-explained and revived by the work of excavators. The chapter of early Sumerian history which was being unveiled through the activities of the British Museum and the Museum of

the University of Pennsylvania, that old new chapter which was now being revealed, was surely as interesting and as brilliant as any of those that had gone before. He had been interested and almost amused by the little toilet set consisting of earpick, tweezer and scalp picker which had been shown on the screen, because almost identically the same objects had been found over and over again in Anglo-Saxon and other graves of early times. So exactly similar were those which could be seen in the Antiquities Room of the British Museum that surely it must be the case that there was a continuous tradition. They were found at all events in Roman diggings and they were found again and again in Anglo-Saxon cemeteries. If it was a case of continuous tradition it was only an example of what was a perfectly established fact, namely, that the past civilisations of the world had handed on a portion of their achievements from generation to generation.

Dr. Hall had given a most delightful and interesting and most valuable exposition of the subject. It was obvious that all those present wished to express to him their gratitude and appreciation.

MR. J. M. WILSON (formerly Director of Public Works and Antiquities, 'Iraq) said that he had listened with very great pleasure indeed to Dr. Hall's delightful lecture. It had awakened very pleasant memories for him. He had not the pleasure of meeting Dr. Hall when he was working in Iraq, but although he did not meet him face to face, he met him on paper. Dr. Hall prepared some very valuable reports on the monuments out there, and it was his (the speaker's) duty as Director of Public Works to endeavour to comply with his recommendations. He had to patch up a few floors in Babylon and repair the arch of Ctesiphon. Whether he was successful or not, time would show. In 1921, when the late Miss Gertrude Bell started the Department of Antiquities, she asked him (the speaker) if he would act as her assistant. He was only too delighted to accept her invitation, and as Assistant Director of Antiquities he came very closely into contact with the diggings at Ur and with the archaeologists there. He must really pay a tribute to them, for he found them a most delightful body of men. He had preconceived ideas about what an archaeologist should be. He was afraid that they upset these altogether. He found that although they were deeply interested in their work, they were not oblivious to the interests outside that work, and that they were possessed of most of the virtues and vices of the ordinary man.

At Ur he paid many very pleasant visits ; but not all his visits were pleasant. He had to pay one visit every year when he had to take from the archaeologists a large share, the lion's share, of their very valuable finds. He had to assure Dr. Hall and any other archaeologist who might be present how much it pained him to do so. He dare say that it pained them rather more.

The objects which they had seen on the screen, and some of which were to be seen in the British Museum, were extremely interesting ; but what interested him still more was the light thrown by the excavations on the art of architecture and the science of building. One could see quite distinctly in Ur and in other cities of Babylonia early traces of attempts at town planning. One could see the beginning of architectural features which were common in our streets to-day. One also saw very clearly the evolution of the science of building in brick, and could trace it right from its early beginnings up to a very high standard of development. One detail which interested him particularly was the actual history of the brick itself, which was seen very clearly at Ur. One saw it evolve from the unmoulded, unburnt lump of natural clay to a manufactured article which was

unrivalled to-day. He could speak from very painful experience, because in addition to assisting Miss Gertrude Bell in the Department of Antiquities, he had to run the Department of Public Works, and it was one of his duties to make bricks. Although he possessed quite a lot of straw and had modern machinery to help him, he was quite unable to make a brick which equalled the brick of Hammurabi or Nebuchadnezzar. Whether the soil had changed, which was just possible in a deltaic country, or whether the early people possessed a secret which had now been lost, he did not know, but the fact remained that he could not make such a brick. The excavations had disclosed many wonderful things, they had revolutionised our ideas of early history ; but he thought that Dr. Hall would agree with him when he said that there were still many fields, vast fields, which had to be explored, and that there were vast new discoveries to make. He sincerely hoped that the work so ably begun by Dr. Hall and Mr. Woolley would be carried on unhampered to new and even more interesting discoveries.

LIEUT.-GEN. SIR GEORGE MACMUNN, K.C.B., K.C.S.I., C.B. (late Commander-in-Chief in Mesopotamia), said that his share in the work was due to his having a large stock of Turkish prisoners on hand to lend to Dr. Hall. They were pining to do a job of work and did it with great happiness, being well fed.

He spent three years as Inspector-General of Communications during the war on the Tigris and the Euphrates, and he supposed that in that time he did five thousand miles travelling up and down those rivers, sometimes in small steamers and sometimes in launches. The fascination of those ancient mounds and ruins was very deeply borne in upon him at that time. What struck him as most extraordinary was that everything in the country to-day coincided with what one read of about ancient times. The boats were still pitched with bitumen inside and out, like the Ark. He found that as Inspector-General of Communications he was sending the same orders down the river such as King Hammurabi used to send. He had to say that if the Arabs of a certain village continued to steal sacks of corn someone would be shot, or that if a boat was delayed more than twelve hours at any fair on the river the boatmen would be flogged. The country was one in which nothing ever changed. One saw how extraordinarily accurate the old stories and records were. Abraham, when he bought the field of Machpelah so that he might bury his wife, bought not only the land but the trees as well. That seemed rather an unnecessary addition ; but at the present time, if one wanted to buy a bit of land and call it one's own, it was very necessary to make sure that one was buying the trees as well as the land, if there were any trees upon it.

GENERAL NOTE.

OFFER OF A SET OF JOURNALS.—A set of fifteen unbound Volumes of the Society's *Journal*, extending from 1912 to 1927, has been placed at the disposal of the Secretary of the Royal Society of Arts for presentation to a public library or institution which will undertake to bind and preserve them. Applications should be addressed to the Secretary, Royal Society of Arts, John Street, Adelphi, W.C.2.

JOURNAL OF THE ROYAL SOCIETY OF ARTS

No. 3950.

VOL. LXXVI.

FRIDAY, AUGUST 3rd, 1928.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICES.

PRESENTATION OF THE SOCIETY'S ALBERT MEDAL TO SIR ERNEST RUTHERFORD.

The Council of the Royal Society of Arts attended at Clarence House on July 26th, when H.R.H. the Duke of Connaught, K.G., President of the Society, presented the Albert Medal for 1928 to Professor Sir Ernest Rutherford, O.M., F.R.S., "for his pioneer researches into the structure of matter."

The members of the Council present were:—Sir George Sutton, Bt. (Chairman), Lord Askwith, K.C.B., Captain Sir Arthur Clarke, K.B.E., Sir Dugald Clerk, K.B.E., F.R.S., Sir Robert Hadfield, Bt., F.R.S., Col. Sir Arthur Holbrook, K.B.E., M.P., Major Sir Humphrey Leggett, R.E., D.S.O., Sir Reginald Mant, K.C.I.E., C.S.I., Sir Richard Redmayne, K.C.B., Mr. A. A. Campbell Swinton, F.R.S., and Mr. Carmichael Thomas, with Mr. G. K. Menzies (Secretary), and Mr. W. Perry (Assistant Secretary).

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A report on the competition, including full lists of awards will be available at the Imperial Institute on August 4th, and published in the *Journal* later.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES

SCIENTIFIC FOUNDATIONS OF THE REFINING OF PETROLEUM.

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I.

GAS AND GASOLINE.

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It is of more than passing interest to realise that the late Sir Boverton Redwood delivered the Cantor Lectures in this historic hall so long ago as 1886. He took as his subject Petroleum and its products, and in the compass of four hours he dealt in a masterly and exhaustive way with this great theme. How impossible to do it justice to-day in such a period of time! Forty years ago we find the eminent lecturer delving into the records of antiquity and summarising the early history of petroleum and developing his subject to the beginning of our own generation, discussing the general geology of petroliferous formations and proceeding to the chemical and physical characteristics of mineral oil as they were then known. He described in considerable detail the method of winning oil as practised by the ancients and by more modern methods—methods that have changed singularly little since 1886. Transport of the raw material from the field to the refinery is to-day much as it was in those early days, but it is on referring to the last two lectures that we realise the tremendous progress that has been made in four decades. In these lectures the author discussed the refining and application of petroleum. Distillation at that period was merely the boiling of oil and the condensation of its vapours, with little or no attempt at fractionation, whilst refining was, in effect, a more or less brutal attack by means of strong sulphuric acid. There are, however, indications of methods that foreshadow modern development, and an outstanding case is the reference to the "cracking" of heavy hydrocarbons as practised at Nobel's refinery at Baku, whereby good yields of aromatic compounds were obtained. Very significant is the statement that "by far the most important of the uses to which the products of petroleum are as yet applied is that of illumination." In an eloquent epilogue the lecturer emphasised the claims of petroleum to have been a potent civilising influence, and suggested that "the degree of mental culture of a nation may be measured by the quantity of mineral oil consumed."

Not only was it true that in the late war the "Allies floated to victory upon a sea of oil," but, also, it is equally true to-day that our everyday life depends for its existence, its amenities and its luxuries upon petroleum. Twenty-five million motor vehicles of all sorts not only transport ourselves, but our food and our raw materials. Civil and military aviation make an ever-increasing demand on mineral oil, whilst the great navies of the world would lose their wide radius of action did they not function on liquid fuel. Yet, as Sir John Cadman (*United Empire XVIII*, 1927, 82) has justly remarked, "it is reasonably safe to predict that the "to-morrow" of petroleum (using the word in its most comprehensive sense) will far outshine even the brilliance that to-day attends its achievement. . . . Remarkable as may have been the use of oil during the last fifteen years, there are indications that by the development of new processes and of more economical methods we shall shortly enter upon a much more scientific phase in the use of oil."

It is not the author's intention in the present course of lectures to trace the multitudinous developments that have occurred since 1886, having regard to the amazing progress that has characterised the last forty years and the impact of war necessities on technology; it is rather intended to discuss the scientific treatment of petroleum and its products in so far as his personal experience extends.

It will be interesting in the first place to contemplate the world production of petroleum in 1886 and 1927.

TABLE I.
PETROLEUM PRODUCTION IN

1886	AND	1927.
<i>Circa</i> 3,000,000 tons	170,000,000 tons (estimated)	mainly made up from :—
		tons.
	United States ...	... 120,500,000
	Russia ...	... 10,000,000
	Venezuela ...	... 9,270,000
	Mexico ..,	... 9,250,000
	Persia ...	... 5,140,000
	Roumania ...	... 3,720,000

As is the case to-day so it was forty years ago, that America is the foremost producer of mineral oil. But whereas in 1886 the major need of the world was for lamp oil, to-day civilisation demands an extraordinarily wide range of products, namely, a comprehensive range of motor fuels, extraction spirits, paint spirits, white spirits, kerosene for power, heating and lighting, gas oils for fuel and for carburetting water gas, lubricating oils of all degrees of viscosity, switch oils, transformer oils, vaselines, waxes and pitches.

CHEMICAL AND PHYSICAL NATURE OF PETROLEUM.

Mineral oil as it issues from the earth is a mixture of solids, liquids and gases, not only in true physical solution, but also existing in the colloidal state. The gas (natural gas) is in the main, methane, the first member of the paraffin series, but there are also present ethane, propane and butane, together with relatively small amounts of hydrogen sulphide, oxygen, carbon, dioxide, nitrogen, and in some cases helium. According as its content of readily liquefiable hydrocarbon is great or small, so the gas is regarded as "wet" or "dry."

Typical analyses of dry or wet gases are shown in Table II.

TABLE II.

		CH ₄ ,	C ₂ H ₆ ,	C ₃ H ₈ ,	C ₄ H ₁₀ ,	N ₂ ,	CO ₂
Pittsburg (dry) gas	...	84.7	9.4	3.0	1.3	1.6	trace
sp.gr. 0.65	...						
Riverside, West							
Virginia (wet gas)		18.0			78.7	3.3	
sp.gr. 1.38							
Persian Gas after absorption		40	21	18	9	—	H ₂ S
sp.gr. 0.99 to 1.03							12

Although in the earlier days of the industry natural gas was regarded merely as fuel, yet up to 1920, 1,000,000,000,000 cu.ft. were wasted. At the present time it is made use of more and more as a source of gasoline. In 1927, 1,600,000,000 gallons of gasoline were extracted, *i.e.*, about 4 per cent. of the crude oil produced.

The first four members of the paraffin series, methane, ethane and propane and butane are gases, but pentane and other higher members are present, and these are liquid under ordinary temperatures and pressures.

TABLE III. (Burrell).

			Boiling Point.	Critical Temperature.	Critical Pressure.
Methane	...	...	-160°C	-81.8°C	54.9 atmos.
Ethane	...	...	-93	35°C	45.2
Propane	...	...	-37	97°C	44
n butane	...	...	+1	153°C	36
n pentane	...	...	37	197°C	33
n hexane	...	...	71.5	234.8°C	30



FIG. 1.—Gasoline Absorption Plant, showing absorbing columns, still and fractionating towers.

There are two methods by which liquid hydrocarbons are recovered from natural gas (*a*) compression, (*b*) solution (in oil or in charcoal). If natural gas be compressed to a point where the partial pressure exerted by any component exceeds its vapour pressure at the same temperature, that component will become liquid. In this way it is possible, for example, to obtain butane and all the higher members of the paraffin family as liquids, holding in solution methane, ethane and propane. Such a liquid exposed to atmospheric temperature and pressure will be unstable and will rapidly evaporate. It is termed "wild." But if it is allowed to boil under a properly constructed fractionating tower then the gaseous components methane, ethane and propane will evaporate leaving a stabilised product containing butane and the higher homologues. Such gasoline is termed "weathered," or stabilised.

Simple compression as a means of producing gasoline is no longer practised. The operation of compressors is costly, the product "wild," and the extraction

difficult to bring to completion. In conjunction with stabilisers of the fractionating tower type, however, the compression process has taken on a new lease of life, especially for rich natural gases and refinery gases.

In a typical compression plant, 2,000,000 cubic feet of gas are dealt with per day and 5,000 gallons of gasoline are obtained. The first stage of compression is to 40 lbs. per sq. in. and the second from 40 to 250 lbs. per sq. in. The hot compressed gas from the low stage compressor is passed through a cooler and any gasoline produced is separated in a tank, the gas passing on to the high stage compressor from which a smaller separation is brought about. The gas from this last separation is residue gas substantially free from gasoline.

TABLE IV.

TABLE SHOWING GAS ANALYSES (Burrell).
BEFORE AND AFTER EXTRACTION OF GASOLINE.

Gas.	Sp. Gr. Air = 1.	Composition	
		Ethane.	Propane.
Natural Gas as drawn from the Well	1.46	10.8	88.3
Residual Gas after compressing to 50 lbs. and removing the Gasoline therefrom		16.9	82.9
Gas remaining after removal of the Compression Products obtained 250 lbs. pressure	1.23	59.2	40.3

This table shows the progressive increase in ethane and decrease in propane and specific gravity with increasing pressure.

The second method whereby the liquid components are removed by absorption is more effective, as the amount of recoverable gasoline becomes less. Usually it is applied by a simple contact between the gas and a solvent such as gas oil, a mineral seal oil, tetralin or even heavy naphtha, or alternatively by a solid adsorbent such as activated charcoal.

Clearly the important factors are the intimacy of contact between the scrubbing liquid and the gas and, further, the temperature at which the solution is taking place. The better the contact and the lower the temperature the more effective is the operation.

TABLE V.

Analysis of a Stripping Oil.

Sp. Gr. @ 60°F	= 0.851
Viscosity @ 100°F	= 39 secs (Redwood)
Pour Point	= 25°F
Set Point	= 20°F
I.B.P.	= 232°F
Distilling at 250°C	1%
275°C	29.5%
300°C	59.0%
325°C	80.0%
350°C	92.0%

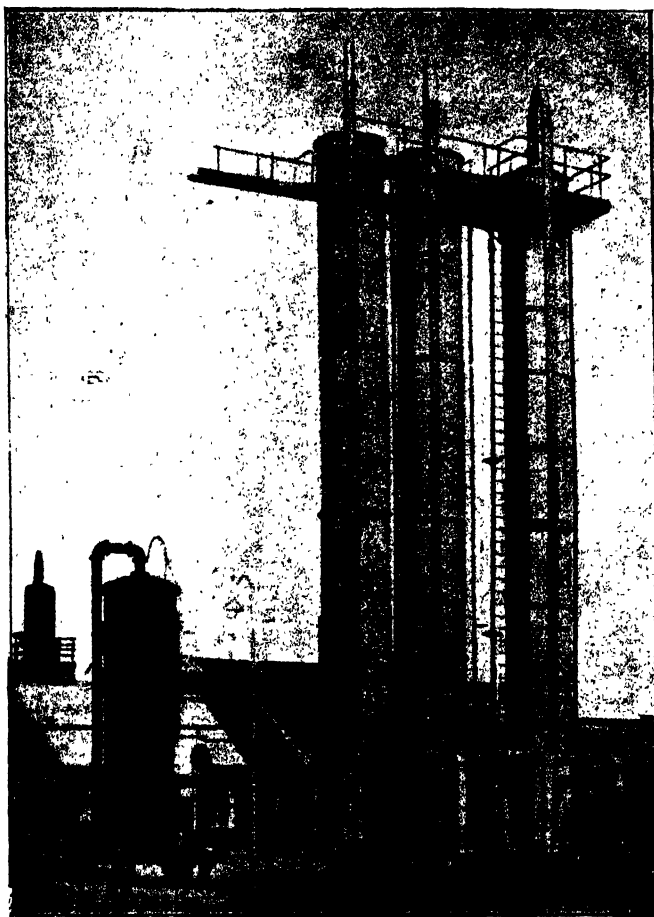


FIG. 2.—Braun Bubble Cap Absorbers for gasoline.

TYPICAL ABSORPTION PLANT.

After the solvent is saturated with gasoline it is distilled, the distillate (less wild than in the case of compression spirit) is condensed and the residual solvent cooled and passed into circulation again.

The diagrams (Figs. 1—5) show the general lay-out of an absorption plant. The tall columns packed with grids or provided with bubble cap decks provide the needed contact between the gas and the solvent. The solution (fat oil) passes to the still, is heated by steam, the vapours pass into an efficient fractionating column, provided at the top with a reflux coil to bring about a predetermined amount of reflux for scrubbing the upcoming vapours, and thence to a condenser.

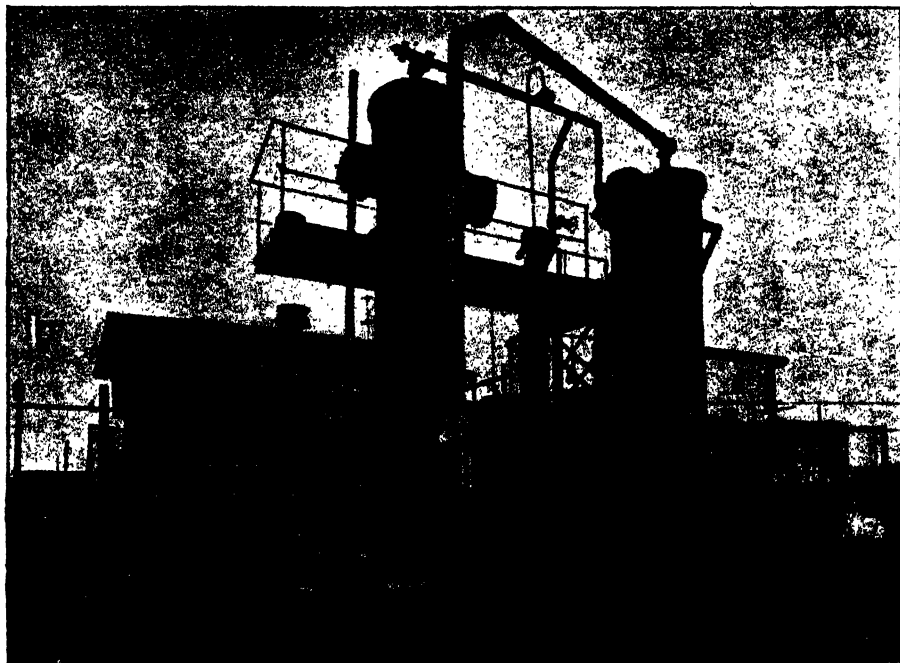


FIG. 3.—Absorption Plant, showing fractionating column.



FIG. 4.—Absorption Plant in the Persian field.



FIG. 5.—General view of an Absorption Plant.

TABLE VI.

Typical recovered gasoline by the absorption process.

Sp. Gr. at 60°F.	...	...	...	...	...	0.650.
I.B.P.	...	...	...	...	...	28°C
Distilling to 50°C	...	...	...	...	...	53%
„ 75°C	...	...	...	...	...	80%
„ 100°C	...	...	...	...	...	87%
„ 125°C	...	...	...	...	...	89%
F.B.P.	...	...	...	...	...	137°C
Loss	...	...	...	...	...	7%

There is given below a description of the activated charcoal process of gasoline recovery, and especially of the Carbo-Union-Bayer Process, for details of which the author is indebted to Mr. Ion Edeleanu.

The absorbent medium "activated charcoal" is a composite material which chemically is characterised by a very high content (about 90 per cent.) of carbon, and physically is characterised by a considerable surface development compared to its mass. In other words, the activated charcoal is a structure of capillaries with a notably great surface. If the capillaries of such a charcoal all had a diameter of 1 millimikron, then the inside capillary surface of a cube of one centimetre base would total about 6,000 square metres. Ordinarily, the activated charcoal has capillaries of different sizes varying from 1 millimikron upwards and the inside capillary surface of a cube of one centimetre base is estimated to be about 600 square metres. Such highly porous bodies possess the property of absorbing gases and vapours.

In fact, it is assumed that two phenomena take place :

1. The covering of the surface of the capillaries with a unimolecular layer of gas ; and

2. The filling of the capillaries with condensed vapours. The first phenomenon depends upon, and is proportional to, the surface ; the second phenomenon, which quantitatively is much more important, depends upon the inner capacity of the capillaries. Gases which cannot be condensed (being above their critical temperatures) will undergo only the first phenomenon, but those vapours which are under their critical temperature, and hence can be condensed, will be adsorbed to a greater extent because they will also undergo the second phenomenon, *i.e.*, condensation and filling of the capillaries.

The charcoal brings about a depression of the vapour tension of the adsorbed liquid. The rate of adsorption depends upon the difference in vapour pressure of the condensed liquid in the capillaries of the charcoal and the partial pressure of the vapour in the gas. The activated charcoal will adsorb and condense greater quantities of vapours if such vapours are present in greater concentration in the gas, because in this case the difference in the vapour pressure of the liquid in the capillaries and the partial pressure of the vapour in the gas is greater. Similarly, the adsorptive capacity of the charcoal decreases at higher temperatures, because the vapour pressure of the condensed liquid in the capillaries will be raised, and hence the difference between this pressure and the partial pressure of the vapour in the gas will be reduced.

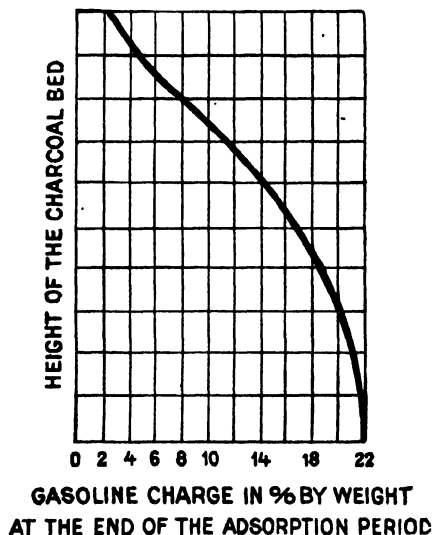


FIG. 6.

The adsorption is very rapid in the beginning of the process, slows up, however, as the charcoal becomes more saturated, and ceases when the pressure of the condensed liquid in the capillaries equals the partial pressure of the vapour in the gas.

Fig. 6 shows the percentage, by weight, of gasoline adsorbed by the Bayer activated charcoal at 25°C, as a function of the concentration of gasoline vapours in the gas. If we reverse this diagram, the same curve (Fig. 7) will show the quantity of gasoline in the residual (stripped) gas, a function of the degree of saturation of the charcoal. It can be seen that at the ordinary degree of saturation, at which plants are operated, the loss is insignificant.

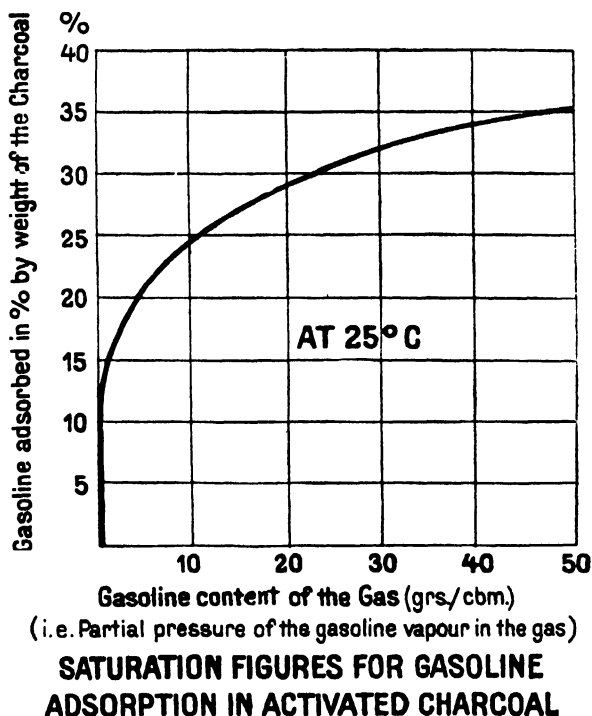


FIG. 7.

Fig. 8 shows diagrammatically the structures of two different kinds of activated charcoal. The samples of these charcoals have been selected to have the same sizes of grains, so there is not much difference in the volume of the voids between the grains. There is a considerable difference between the volume of the solid carbon substance, which is due to the fact that the first charcoal is made from peat and the second one is made from fruit pips. It will be readily understood that neither the voids nor the solid substance will act in the adsorption process. The balance of the volume is the volume of the capillaries. These capillaries are divided according to size into the following three categories:—

1. Capillaries bigger than 100 millimikron.
2. Capillaries between 2 and 100 millimikron.
3. Capillaries smaller than 2 millimikrons.

While the first series of capillaries is too large and, therefore, useless for condensation, the second and third series are very suitable for this purpose. Capillaries of more than 2 millimikrons can condense vapours only when they are present in a certain high concentration in the gas, whereas capillaries of less than 2 millimikrons—series 3—will condense vapours even if such vapours are present only in a very small proportion in the gas.

DIAGRAMATIC REPRESENTATION
OF THE STRUCTURE OF TWO KINDS OF ACTIVATED CHARCOAL
(GRAINS SORTED TO SAME SIZE) 100 cc. CONTAIN :

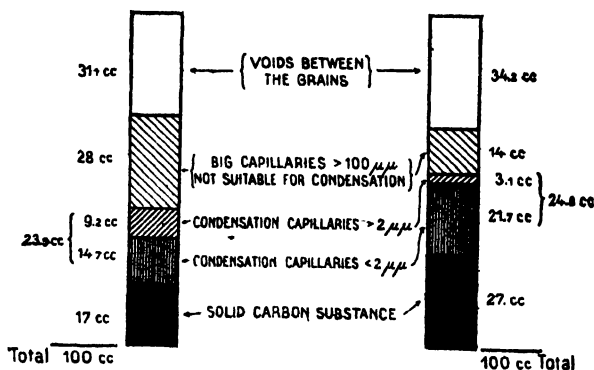


FIG. 8.

The total volume of the capillaries up to 100 millimikrons has been determined by the quantity of benzole adsorbed from a gas saturated with benzole vapours, whereas the total volume of the capillaries up to two millimikrons has been determined by the quantity of benzole adsorbed from a gas only one tenth saturated with benzole vapours. The difference of these two figures has given the total volume of the capillaries of the size between 2 and 100 millimikrons.

The quantitative proportion between the two last-mentioned categories of capillaries is a criterion whether such charcoal is better suited for the recovery of solvents in relatively high concentration or for the adsorption of gases, and full credit should be given Professor Mecklenburg for his research work in this field.

The principal parts of a charcoal gasoline plant are :—

- A. Filters for removing the impurities contained in the gas (dust, oil, etc.)
- B. The adsorbers with activated charcoal.
- C. The condenser and cooler for the distilled vapours.
- D. The gasoline separator.
- E. The blower for the circulating air that is used to dry and cool the charcoal.

These parts of an activated charcoal plant are shown diagrammatically in Fig. 9 and a general view is given in Fig. 10.

The gas first passes through the filter (A) where the impurities, such as dust, oil, etc., are retained. The gas leaving the filter enters one or several adsorbers (B). The cycles are timed so that the beginning of the adsorption in the first adsorber corresponds to the end of the adsorption in the last adsorber. The gas enters the bottom and passes upwards through the adsorbers so that the lower layers of charcoal get charged first with gasoline. The charging of the charcoal is accompanied by evolution of heat and, therefore, the temperatures shown by the three thermometers at the bottom, middle and, upper part of the adsorber indicate the progress of the adsorption.

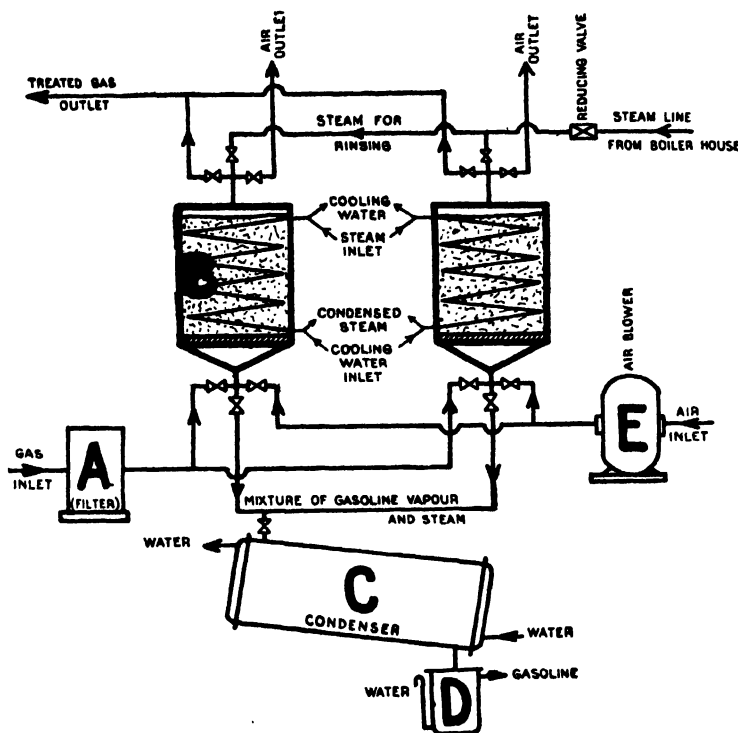
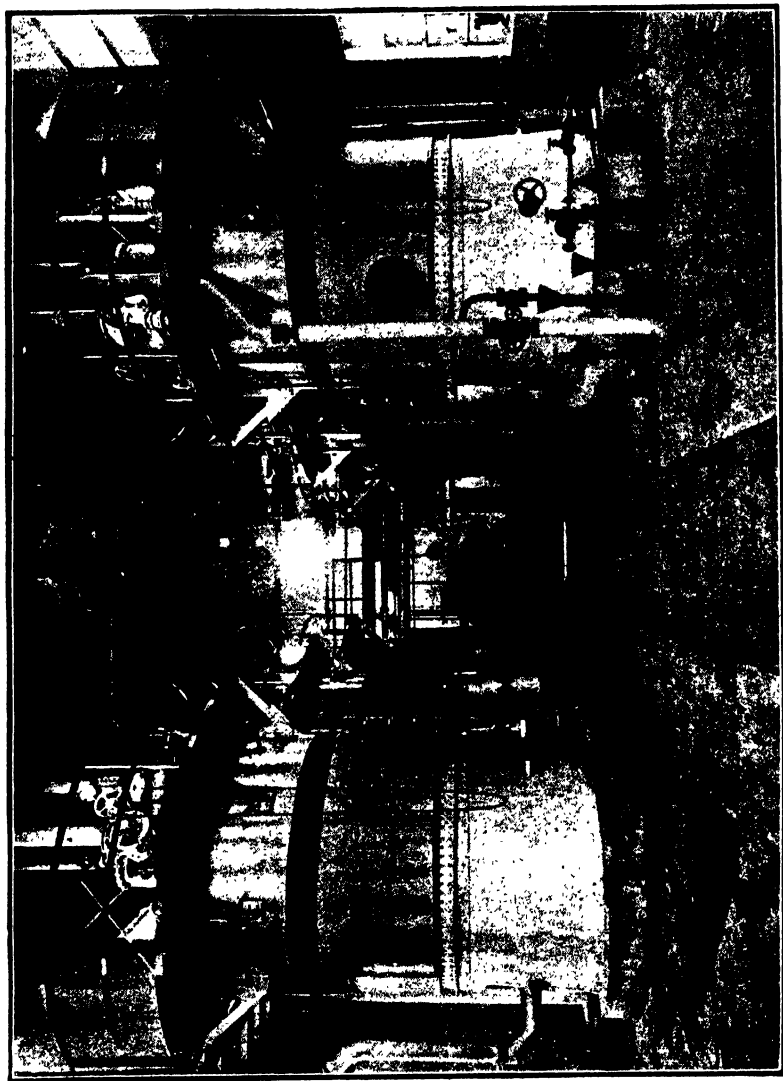


FIG. 9.

The charge of the charcoal is not carried beyond 12 to 16 per cent. of the weight of the charcoal. The degree of charge depends upon the character of the treated gas and upon the quality of the gasoline that it is desired to obtain. This degree of charge of 12 to 16 per cent. is much below the saturation limit of the charcoal, but it is kept so low in order to avoid the loss of useful fractions in the stripped gas. The retentivity of the charcoal drops as the charge approaches the saturation corresponding to the partial pressure of the vapours in the gas.

The charcoal manifests in a high degree the property of selective adsorption, the heavier gasoline fractions displacing and removing the lighter fractions.



F G. 10.—Bayer Plant. Daily production, 20 tons of gasoline.
(*The Phoenix Oil and Transport Co.*)

Thus methane, which in the beginning is adsorbed by the charcoal, is displaced by ethane, which in turn is displaced, as the charcoal gets more saturated by propane and the higher homologues. This phenomenon is accompanied by a slight fall, and then a subsequent rise of temperature, which is due to the negative heat of adsorption of the displaced fraction.

When the desired limit of charge is reached in one of the adsorbers, the gas is turned off and closed steam is turned through the coils. The steam used has a temperature of about 127°C . This indirect heating is not sufficient to eliminate the adsorbed gasoline, and therefore, after a short time, the charcoal

is rinsed downwards with open steam, thus effecting the complete elimination of the adsorbed gasoline.

After the rinsing of the charcoal has been completed, the direct steam is turned off, and air is blown upwards through the adsorber. This air gets heated by the hot coils and dries the charcoal. When the charcoal has reached the desired state of dryness the closed steam is turned off, while the air continues to pass through the adsorber and cools the charcoal. In order to speed up the cooling of the charcoal it is found advantageous to circulate cold water through the coils. The activated charcoal in the adsorbers is ready for a new cycle and the raw gas is passed in again.

Where the gas contains sulphur compounds—and this applies especially to still vapours in certain refineries—poisoning of the charcoal is to some extent prevented by filtering the gas through scrubbers containing a lower grade of activated charcoal. Furthermore, unsaturated hydrocarbons in the presence of activated charcoal polymerise and fill the capillaries with asphaltic material which reduces the adsorption capacity.

In general, it may be said that this process is unsuitable for gases containing a substantial amount of sulphur derivatives, which on oxidation afford elemental sulphur.

THE APPLICATION OF NATURAL GASOLINE.

The application of natural gasoline to the petroleum industry is only relatively new. Briefly, this material supplies readily volatile components to the motor spirit fraction, and, furthermore, by being blended with heavy naphtha, it yields a mixture comparable with the straight run product.

TABLE VII.

Analysis of Natural Gasoline.	Analysis of Heavy Naphtha.	Analysis of Blend.	Analysis of Straight Run Spirit.
S.G. = .651	.771	.721	.725
I.B.P. = 21° C	105° C.	30° C.	38° C.
F.B.P. = 123° C	186° C.	181° C.	173° C.
Off at 50° C = 51.0%	Off at 125 = .5%	Off at 50 = 11.0%	1.0%
75 = 76.0%	150 = 51.0%	75 = 27.0%	15.0%
100 = 88.0%	175 = 95.0%	100 = 37.0%	44.5%
Residue 1.5%	1.5%	125 = 47.0%	73.5%
Loss 0.5%	0.5%	150 = 69.0%	92.0%
		175 = 94.5%	98.0%
		Residue = 1.2%	1.0%
		Loss = 2.3%	1.0%

The effect of this has been to increase the volume of gasoline produced in the U.S.A. by about 15%. The lighter components of natural gas, *e.g.*, propane and butane, condensed under pressure, form a useful material for replacing acetylene in oxy-gas welding and are marketed in cylinders under the name of Gasol.

The residual methane and ethane may be employed as fuel, but if burnt in a limited amount of air they yield carbon black, a particularly finely divided form of elemental carbon that is used as a pigment and dispersed in rubber as a filler, especially in the manufacture of motor tyres. The extremely high degree of dispersity confers on the rubber a degree of durability and elasticity so desirable in a wear-resisting article.

Seeing that methane is the source of this elemental carbon, the yield of the black is only of the order of 1 or 2 lbs. per 1,000 cu. ft., which is a disappointingly poor return, but the thermal decomposition of methane has been worked out in other ways, notably by Szarvasy (E.P. 159, 823) who, by the effect of very high temperature obtains theoretical yields of carbon in a particularly pure form and of hydrogen. Furthermore, the so-called thermatomic carbon (Brownlee) although obtained in a far better yield, is not apparently a superior product.

The lower paraffin hydrocarbons in natural gas have always attracted the attention of the chemist, because of the possibility of their being employed as a source of synthetic compounds. From time to time attempts have been made to obtain on the commercial scale formaldehyde, methylchloride, chloroform, carbon tetrachloride and the like. (see p. 91).

UTILISATION OF GAS.

The enormous production of gas has always made the problem of its utilisation one of extreme interest. The composition of the gas varies with the conditions under which it is separated from the oil, but it consists practically entirely of paraffins and hydrogen sulphide (in the case of Persian and Texas gases). The higher members of the paraffin gases and hydrogen sulphide are more soluble in oil under pressure than the lighter gases, and consequently gas separated at a high pressure (*e.g.*, Dome gas) consists almost entirely of the light gases methane and ethane.

A sample of Persian gas separated at 400 lb. pressure was found to give the following analysis :—

TABLE VIII.

Hydrogen Sulphide	.9% by vol.	Hydrogen	nil by vol.
Carbon-di-oxide	.35% „	Paraffins	96.36% „
Oxygen	.25% „		

On the assumption that only ethane and methane were present the proportions were :—

Methane	...	...	80.2%
Ethane	...	...	16.16%

When the gases are separated at lower pressures higher members of the paraffin gases are present, and considerable quantities of petrol are also carried away.

The quantity of hydrogen sulphide carried by the gas also increases. Thus, whilst very high pressure gas contains only about 1% of hydrogen sulphide, it is possible after removal of some of the high pressure gas to obtain low pressure gas containing 15% of hydrogen sulphide.

THE GASOLINE CONTENT OF NATURAL GAS.

The volume of gas liberated from the oil at various pressures and its gasoline content have an important bearing on the design of plant necessary for its extraction. The laws governing the gasoline content are very simple. In a mixture of liquids such as crude oil each constituent exerts a definite partial pressure which increases with rise of temperature. Any gas contained in the space above the liquid will be saturated with the vapours of the light constituents of the oil at their particular partial pressure. The light constituents of the crude oil which forms the natural gas gasoline are found to exert, when dissolved in the crude oil, almost the same vapour pressure as pure pentane, and the gas contains almost the same amount of them as it would if any gas and pure pentane were in a space together. If a gas and liquid pentane were present in a space under a pressure of 6 atmospheres a certain quantity of the pentane would be present in the form of vapour in the gas. If the gas were allowed to escape to atmospheric pressure out of contact with the liquid pentane the quantity of pentane in the gas would remain the same, but the volume of the gas would be increased six times. The actual amount of the pentane per cubic foot would therefore be only $\frac{1}{6}$ th of that amount in one cubic foot of the gas when under pressure, and only $\frac{1}{6}$ th of that which would be carried by the gas if it were allowed to bubble away through the pentane at ordinary pressure. The same thing occurs when the natural gas escaped from crude oil, and the gasoline content is governed by the pressure at which the gas is allowed to escape and also on the temperature. Curves have been constructed showing the gasoline content of natural gas when liberated from oil under various conditions of temperature and pressure, and show the importance of the conditions under which separation of oil and gas are made. It is known that the gasoline content increases very rapidly with rise of the temperature of separation of the gas from the oil. This will probably occur in summer, when the difficulties of recovery are greater.

THE CONVERSION OF NATURAL GAS INTO LIQUID PRODUCTS.

In view of the large quantities of natural gas that are available, work has been carried out on the conversion of the gas into liquid products. The most successful side of this work has been that which has been directed at the conversion of the higher paraffin gases, ethane, propane, and butane into benzol. Gas separated at high pressures contains some 16% of ethane, and that separated at lower pressures contains considerable quantities of the heavier gases. The formation of benzol when these gases are heated to high temperatures has

been known for some time, and in the case of coal gas some effort has been made to increase the benzol content by further heating. It is only recently, however, that any effort has been made to obtain benzol by the action of heat on natural gases. On the purely scientific side the action of heat on ethane has been investigated under various conditions (Williams Gardner—*Fuel in Science and Practice*, 1925, 10, 430) but early investigations were commenced in 1922. As a result of this work it was found that between 800 and 900°C in silica vessels some 15-25% of ethane is converted into considerable products of which benzene and naphthalene formed a large part. Working on pure ethane it was found that the best temperature for the maximum yield of liquid products was 809°C, and valuable information as to the reactions which took place was obtained. High pressure and low pressure gas of the following composition were studied in the light of this work :—

TABLE IX.

					High Pressure Gas.	Low Pressure Gas.
Hydrogen Sulphide	...	...	...	...	.9%	7.8.
Oxygen and Carbon Dioxide	...	...	...	...	.7%	1.94%
Nitrogen	...	...	...	...	1.4%	1.7%
Methane	...	...	...	...	81.0%	36.0%
Ethane	...	...	...	...	16.0%	32.0%
Propane	...	...	...	...	-	9.0%
Butane	...	...	...	...	-	9.0%
Pentane	...	...	...	...	-	6.0%
Density (H=1)		...	...	...	11.8	16.7

Hydrogen sulphide was first removed by washing the gas with caustic soda and the gas then passed through a vertical silica tube 2 in. in diameter, and electrically heated. A certain amount of tar fog is produced, and this was removed by means of a Cottrell electrical precipitation apparatus. The light spirit produced was carried forward by the gas and collected by passing the gases through a tube containing activated charcoal. From the high pressure gas 1 c.c. per cubic foot of light spirit was obtained and from the low pressure gas 3.5 c.cs. per cubic foot were obtained. This is equivalent to 220 gallons and 770 gallons per million cubic feet respectively. On distillation the spirit was found to have an initial boiling point of 57°C and a final boiling point of 150°C, about 70 per cent. distilling over between 80 and 90°C. The product had a gravity of .878 at 15.5°C. It consisted almost entirely of aromatic hydrocarbons the greater part benzol. In addition to the light spirit a quantity of aromatic tar was obtained.

OTHER METHODS OF GAS UTILISATION.

The major part of natural gas is methane, this forming 80 per cent. of the high-pressure gas, and this gas is not so susceptible to direct conversion into

liquid products as the higher members. One of the most promising lines of attack is to convert it into a mixture of carbon monoxide and hydrogen, which is easily done by passing the gas mixed with steam through tubes heated to about 900°C , and then utilising the gas mixture thus formed. During recent years considerable research has been done on the conversion of mixtures of carbon monoxide and hydrogen into liquid products. One of these is the production of synthetic methyl alcohol, which is now worked on a large scale (see p. 93). This gas mixture can also be converted into other oxygen containing compounds, and into petrol and paraffin like substances. It has been found that when carbon monoxide and hydrogen are passed at ordinary pressures over catalysts, prepared by reducing the oxides of iron, nickel, cobalt or other metals with hydrogen at $300\text{--}500^{\circ}\text{C}$. and heated between 225 and 300°C ., petroleum-like oils and waxes are formed, and the formation of oxygen containing substances such as methyl alcohol is inhibited.

THE REMOVAL AND RECOVERY OF SULPHUR FROM GAS.

Hydrogen Sulphide.—Hydrogen sulphide is a constituent of some natural gases, but rarely rises to more than 2%, although in Persia and Texas it may rise to over 10%. Hydrogen sulphide is exceedingly poisonous and has the objectionable properties of readily oxidising in the presence of air, and of forming elemental sulphur which is exceedingly corrosive; consequently gasoline extracted from gas containing sulphur must be purified at the earliest moment, or, alternatively, the gas itself must be freed from hydrogen sulphide.

It has already been pointed out that the presence of hydrogen sulphide in the gas renders ineffective the charcoal separation method.

The chemistry of the treating of gasoline will be dealt with later, but it may be mentioned at this stage that natural gasoline can be effectively desulphurised either by the use of alkaline hypochlorite or by treatment with a solution of sodium plumbite.

In modern practice the gasoline is treated in a counter-current enclosed continuous apparatus, which gives the needed treatment and obviates evaporation losses. A typical plant for the refining of gasoline by means of sodium hypochlorite consists of a treating tower four feet in diameter and twenty feet high, filled with distributor plates and packing. It contains a solution made up by passing 200 lb. of chlorine into a solution of 150 lbs. of caustic soda dissolved into 200 lbs. of water. Gasoline passing from the stabilising plant is sprayed into the bottom of the tower, it rises through the hypochlorite solution and overflows at the top into tank. The solution separating at the bottom of the tower is run off from time to time to be replaced by fresh liquor. The consumption of chlorine is 0.3 lbs. per ton of gasoline.

A method for recovering sulphur from gas which has been investigated is an adaption of the Claus Sulphur Recovery Process. When the proper amount

of air is mixed with natural gas containing hydrogen sulphide and the mixture passed over catalysts maintained at a suitable temperature, sulphur is liberated and may be collected.

HELIUM.—This element is occasionally present in natural gas varying from a trace up to 2%.

Interest was taken in this element during the War for use in airships owing to its remarkable inert behaviour. Its chemical inactivity and its lightness make it ideal for this purpose, for it has 92% of the lifting power of hydrogen. Those natural gases that contain nitrogen usually contain some helium. For example, the natural gas of the Petrolia Fields, Texas, that contains 35% of nitrogen contains also 0.9% of helium, and from this observation there was developed the U.S. Government's Helium Plant at Fort Worth.

The process of extraction is one of liquefaction. By cooling the gas all other constituents are liquefied; for helium boils at 74°C. lower than nitrogen. It is safe to predict that where helium is found to exist in comparatively large amounts in natural gas, there would be considerable development in airship practice.

STABILISATION OF NATURAL GAS.

It has been shown previously that the presence of propane in natural gas, and particularly in compression gasoline, brings about undesirably high vapour tensions. Credit for attempts to separate propane from the other hydrocarbons is due to the National Carbon Company, and the first plant has been described by Rafferty in a paper read before the Association of Natural Gasoline Manufacturers, Tulsa, in 1923.

In effect, the crude gasoline is introduced into a rectifying column under pressure where it expands. The most volatile material is introduced near the top, and as it expands the temperature is lowered; there is thus a temperature gradient down the column and into a receiver connected with the bottom of the column. This receiver is provided with a steam coil. The stabilised gasoline is withdrawn from this vessel and the propane leaves the column at the top. To illustrate the effect of propane on vapour pressure the following table (Burrell) may be quoted :—

TABLE X.

Propane Content by Weight.	Vapour Pressure at 100° F. lbs. sq. in.	I.B.P. °F.	F.B.P. °F.	Distillation Loss.
0	13	67	266	9
2	16.5	64	264	13.5
3	18.5	61	263	19
4	21	57	262	22
5	23.5	53	261	25.5

The Rafferty stabiliser is a definite improvement in the utilisation of natural gasoline, so much so, that at the moment of writing stabilised gasoline has been put forward seriously as a complete motor fuel, *i.e.*, entirely independent of any blending whatsoever.

TABLE XI.
VAPOUR TENSIONS OF NATURAL GASOLINE.

Temp.	Vented Compression Gasoline.	Stabilised Gasoline.
	Abs. Press, mm/Hg.	Abs. Press. mm/Hg.
20	1900	950
40	1750	1650
60	2900	2650
80	4500	4100
100	6700	6250

TYPICAL STABILISING PLANT.

The fractionating tower is a well lagged, bubble cap column, with three points of entry at different levels. The latent heat of evaporation is made use of to maintain a very low temperature at the top, whilst steam heating gives a thermostatically controlled temperature of 60°F. at the bottom. The normal absorption gasoline that has been condensed under 30 lbs. pressure is introduced near the bottom of the top section, which contains fifteen bubble decks. The vapours from the stock tank, accumulator tanks and from the top of the stabiliser are collected, compressed to 50 lbs., and, after cooling, the condensate is injected into the middle of the column. The wildest gasoline is injected on to the fourth plate from the top and the temperature due to its evaporation is about -15°F. Pressure and temperatures are automatically controlled.

The De Brey Stabiliser consists of a very efficient bubble plate fractionating tower, with a closed steam heated boiler at the bottom and heat exchange equipment—all built to withstand 250 lbs. sq. inch pressure. A reflux condenser is incorporated in the top of the tower. The tower is 4 ft. diameter, 30 ft. high, containing 26 bubble plates with inlet connections to each of the bottom ten plates.

Operating Conditions.—The high pressure accumulator is a long cylinder containing the wild product, and has a float level control which operates the feed valve to the tower. The feed passes through two exchangers where its temperature is raised to 150°F. It is injected on to the fourth plate from the bottom. The boiler has a temperature controller operating the closed steam supply and is kept at 230°F. This hot stable product passes away through the exchangers and final coolers and is trapped to the make-tank, from which by level control it is fed to storage.

The temperature at the top of the tower is 100°F and the vapours pass into a reflux condenser having its cold water supply controlled by the temperature of the refluxed liquid, keeping the latter at 80°F. The vapour leaving the reflux at 80°F. passes through a pressure controller which maintains a pressure of 185 lbs/sq. inch on the whole apparatus. This pressure is sometimes as high as 200 lbs., being controlled according to the quality of product desired.

TABLE XII.

ANALYSES OF GASOLINES (Rafferty).

Constituent.	Absorption Gasoline for Blending. (1)	Weathered Com- pression Gasoline. (2)	Absorption Gasoline. (3)	Absorption Gasoline. (4)	Stabilised Gasoline. (5)
Ethane	.0	.1	.1	.0	.0
Propane	5.0	3.9	3.2	1.6	0.0
Butane	55.2	21.8	19.2	14.8	40.2
Pentane and Higher Hydro- carbons	42.8	74.2	77.5	83.6	59.8
Vapour Pressure lbs. per sq. in. at 100° F.	25	20	16	13	13

It will be seen by the above table that No. 5 is a well-stabilised gasoline that can be handled easily and shipped without blending. Furthermore, it is clear the presence of propane materially increases the vapour tension. The presence of butane is unobjectionable, normal, and, in fact, desirable, and at the present moment in many stabilising plants propane-free gasoline is being produced on a very large scale.

Natural gasoline to-day amounts to rather more than 12 per cent. of the total gasoline produced in America, and attention has been drawn recently to two specific advantages which it possesses, either when used alone or employed as a blend. The first of these is volatility, more particularly, volatility at low temperatures. The fuel must possess enough volatility to produce an explosive mixture for starting purposes, and in recent years, owing to the gradual diminution of volatility, manufacturers have equipped their engines with heated induction systems. The heating of the charge before admission to the cylinder is undesirable, bringing about reduction in power and increasing the tendency to knock.

The anti-knocking quality has also been definitely established. For example, a stabilised gasoline from an absorption plant, compared with the straight run benzine from the same crude, possessed a benzole equivalent of thirty per cent., but American opinion seems to indicate that a straight natural gasoline is about half as effective as benzole.

EXHIBITION OF ANTIQUES AND WORKS OF ART AT OLYMPIA.

ORGANISED BY "THE DAILY TELEGRAPH."

SOME INTERESTING PERIOD REPRODUCTIONS.

Some of the most romantic periods in our country's storied past were represented at Olympia in the exhibit of the House of Waring and Gillow, who displayed, in a suite of five rooms, interiors characteristic of the periods from James I to George III.

The exhibit was distinguished throughout by the accuracy with which the several régimes were presented. The earlier rooms, in the Jacobean manner, were shown in the original panelling; while a Queen Anne parlour and a Chippendale bedroom were designed to reproduce with equal faithfulness the rooms of their respective periods. Some fine antiques figured in each room, and the reproductions of contemporary furniture were of a very high order of excellence.



Queen Anne Painted Parlour Exhibited by Waring and Gillow at Olympia.

Rich in historic association was the Marlborough Hall, with its handsome staircase, which formed part of the town house of the renowned military leader John Churchill, first Duke of Marlborough. Some noticeably fine features in this Hall were a Sheraton bookcase with beautiful tracery doors; two Hepplewhite settees; and a Charles II Console table, with carved under-part in the original gilt.

The Queen Anne painted parlour was a charming room architecturally representative of the early XVIIIth century. Of particular interest here, were an old Queen

Anne walnut chair, with cabriole legs and old needlework seat, and a Queen Anne spinning wheel. The Queen Anne panelled room, containing woodwork taken from an old house in Worcester, made an effective setting for some interesting William and Mary chests. The James II chairs in carved walnut shown in this room were from the Donaldson Collection and from New Hall, Macclesfield.

The Jacobean room, in panelled oak of the period 1603-1649, was an especial joy to the lover of antiques. The restful simplicity of the panelling and fireplace was typical of East Anglian architecture in the early XVIIth century and, indeed, the panelling was only recently removed from a house of that period at Yarmouth.

A pleasing Chippendale bedroom contained antiques and reproductions of the period 1740-1780, the outstanding feature being an example of a canopy bed.



Marlborough Hall Exhibited by Waring and Gillow at Olympia.

It is not surprising that Messrs. Waring and Gillow should have staged such a prominently interesting representation of period furniture, for investigation of the firm's history reveals a long and intimate association with the furnishing craft. It was in 1695, in the reign of William and Mary, that Robert Gillow established his cabinet shop in old-world Lancaster. The Gillow family was in close touch with those masters of craftsmanship, Chippendale, Hepplewhite, Sheraton, Kent and the brothers Adam; and the furniture made by Waring and Gillow to-day faithfully reflects the spirit of those great artificers in wood. It is even manufactured in an atmosphere retaining those early associations, the firm's factory at Lancaster being on the actual site of its founder's first shop.

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PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES

SCIENTIFIC FOUNDATIONS OF THE REFINING OF PETROLEUM.

By A. E. DUNSTAN, D.Sc. (London), F.I.C., F.C.S.

Vice-President and Editor of the Transactions of the Institution of Petroleum Technologists; Chief Chemist, The Anglo-Persian Oil Co., Ltd.

II.

DISTILLATION METHODS.*

(Delivered January, 1928.)

During many years the petroleum refining industry has been developing, step by step, from the old rule of thumb methods, and approximating steadily to a perfection of plant control that is only obtainable by the application of accurate and scientific procedure. Early distillation plant consisted of flat-bottomed cheese-box stills and simple worm condensers. Frequent re-distillation had to be employed, but there was little need for sharp fractionation seeing that in the early days almost the only product was kerosene, gasoline being, in fact, an objectionable waste material, whilst at the heavier end lubricating oils derived from petroleum were as yet unknown. Step by step an increasing degree of fractionation became desirable, until to-day the perfection and efficiency long ago obtained in the alcohol industry has been attained in petroleum refineries, and the large area previously covered by

* The author is indebted to the Editor of *The Industrial Chemist* for permission to make use of his article on Distillation that appeared in the December issue, 1927.

primary stills and re-distillation units is now unnecessary, seeing that a simple equipment, consisting of a tube still, fractionating column, heat exchangers and condenser, is sufficient. The appearance of the tube still, long known, in point of fact, in the coal tar industry, only became possible in the mineral oil refinery when its value had been conclusively proved in modern cracking plant with its accurate control of heat, pressure and velocity.

THE PIPE STILL.

A large part of the heat required in the distillation of petroleum is recovered in heat exchangers and applied in the preliminary heating of the charge to the still, and this, in conjunction with the saving of steam that is used in the shell type of still, is an extremely important item in reducing refinery costs.

In the design of the modern tube still it is of first importance that all the oil passing through should be heated to the maximum temperature desired and none should be heated beyond this temperature. Consequently, accurate control at every stage is required. The stream of oil being heated whilst passing through the pipe gradually increases in velocity as it passes from the cooler to the hotter zones, a greater degree of turbulence being obtained by the formation of bubbles of vapour in the stream. This high velocity is essential not only to ensure uniform heating, but also to obtain a maximum degree of transfer in the shortest time to avoid pyrolysis at the hot surfaces. It is now well known that at temperatures lower than those required for the so-called cracking of oil there occurs a molecular rearrangement that operates in two ways. Firstly, there is produced less viscous oil of lower molecular weight than that of the original material, but not so low as is likely to affect the flash point, and secondly, unsaturated compounds are formed that increase the difficulty of subsequent refining. The construction of a pipe still is similar to that of a water-tube boiler, and the operations in each case are very analogous. Any type of fuel may be burned and the thermal efficiency is high. The furnace gases pass over banks of the tube system counter-current to the flow of oil. Preheated air may be used for obtaining higher efficiency. The tube heater and fractionating equipment include the following details :—

1. Heater coils.
2. Flue gas re-circulation device.
3. A preheater.
4. Circulating pumps.
5. Heat exchangers.
6. Fractionating column, also automatic apparatus for controlling pump speed, liquid levels and temperature.

By incorporating in the furnace a set of tubes to absorb radiant heat and by introducing the air preheated higher efficiency is obtained. The re-circulation of a proportion of flue gases assists in maintaining uniformity of temperature in the combustion chamber. The result is that the maximum temperature of the combustion chamber averages 900°C., whilst the temperature of the gases passing over the tubes is maintained at about 700°C. The transfer of heat by means of radiation is becoming increasingly appreciated, and larger parts of the heating surfaces are being exposed to radiation from the combustion gases and

walls of the furnace. In pipe stills of recent construction the efficiency has been vastly increased by exposing practically the entire surface to radiation, leaving only a small proportion of energy to be absorbed in the convection section for preheating purposes. By careful control of temperature there is a minimum carbon deposit in the tubes, and in point of fact the maintenance cost of this setting and the cost of cleaning tubes is in no way greater than that of a shell still of the same capacity.

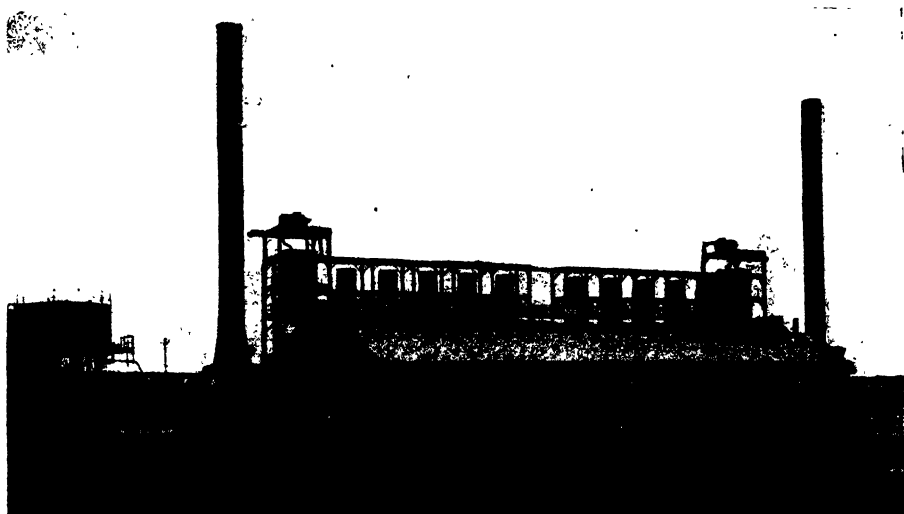


FIG. 11.—A typical shell still installation for topping crude oil. Preheaters are seen at each end of the Bench.

The simplest type of tubular equipment is that in which the crude is first heated in the exchangers and then in a continuous coil. An alternative treatment is achieved when the heat is applied in three stages, the gasoline being vaporised by the heat absorbed in heat exchangers. After removing the gasoline the oil is passed into the first stage of the coils in the furnace and then discharged into a vaporising section, from which the bottoms are pumped into the higher temperature zone of the still. This again passes to a vaporiser, the bottoms of which are run off as residue.

Perhaps the most striking feature about the combination of pipe still connected with a modern fractionating column is its flexibility. Not only may crude oil be run to gasoline, kerosene, gas oil, wax distillate and a pitch residue, but also the same unit may be used on a much higher throughput for topping, and with this difference from the conventional crude oil and re-distillation plant that sharply-cut fractions may be obtained. Comparing this performance of shell stills and pipe stills, the following data quoted by Leslie (*Journ. Inst. Petr. Techn.*, 1927, 13, 551) is instructive. The batch stills and pipe still operated at the same final temperature, viz., 590°F., and in the former case 54

per cent. was vaporised, whilst in the latter 77 per cent. was removed. The residue in the former case contained 2.4 per cent. (on the crude) boiling below 450°F., whilst in the latter there was less than 0.1 per cent. Approximately, for equal work done the final temperature at the pipe still may be 100°F. lower than that obtaining in the batch process.

THE COLUMN.

Much interest has been aroused by the analysis of the methods of vaporising crude carried out by Leslie and Good (*Journal Industrial and Engineering Chemistry*, 1927, 19, 453-460). These investigators studied two methods of vaporisation, namely, the single and successive flash. The former means the bringing of the whole mass of crude to a pre-arranged temperature and allowing vaporisation to take place at that temperature, intimate contact being maintained until equilibrium is established. On the other hand, successive flash implies vaporisation in stages, at each stage equilibrium vapour being removed and the residue again reheated for the next stage. For topping purposes the single flash method is probably the most economical, but where the crude has to be run to a low residue the successive flash is the better. Comparing single and successive flashings, Leslie and Good (*loc. cit.*) note that the proportion of single flash distillate boiling below the flash temperature is 82.3 per cent., whilst for successive flash the figure is 80.65 per cent. The end point (A.S.T.M. method) is about 150°F. above the flash temperature for single flashing, and for successive flashing 135°-140°.

In Fig. 16 is seen a combination of pipe still and bubble tower designed to remove 90 per cent. distillate from Mid-Continent Crude at a capacity of 5,000 barrels per day, or to take 50 per cent. from the same crude with a throughput of 10,000 barrels per day (Primrose, *Oil and Gas Journ.*, December 2, 1926). The bubble tower designed by the Power Specialty Company contains decks provided with long apertures arranged parallel to a diameter over which are long serrated covers maintaining a liquid seal and provided with two down-discharge pipes delivering condensate to opposite sides of the next deck. Corresponding decks in the equipment, supplied by Messrs. Badger, of Philadelphia, are fitted with a large number of apertures, each surrounded by a hemispherical serrated cap. In either case the design permits of most intimate contact between the vapours and the down-passing condensate.

On the top of the column is admitted reflux in a pre-determined quantity, either by means of a reflux condenser or by pumping from the appropriate condensate tank. If the crude is corrosive, then the latter method is to be recommended. Appropriate fractions may be withdrawn from various decks in the column, and at various stages additional reflux may be introduced and stripping, sections provided. The whole apparatus, in fact, replaces the separate devices used on the multiplicity of shell stills, and with this advantage, that at every stage there is accurate control of temperature and

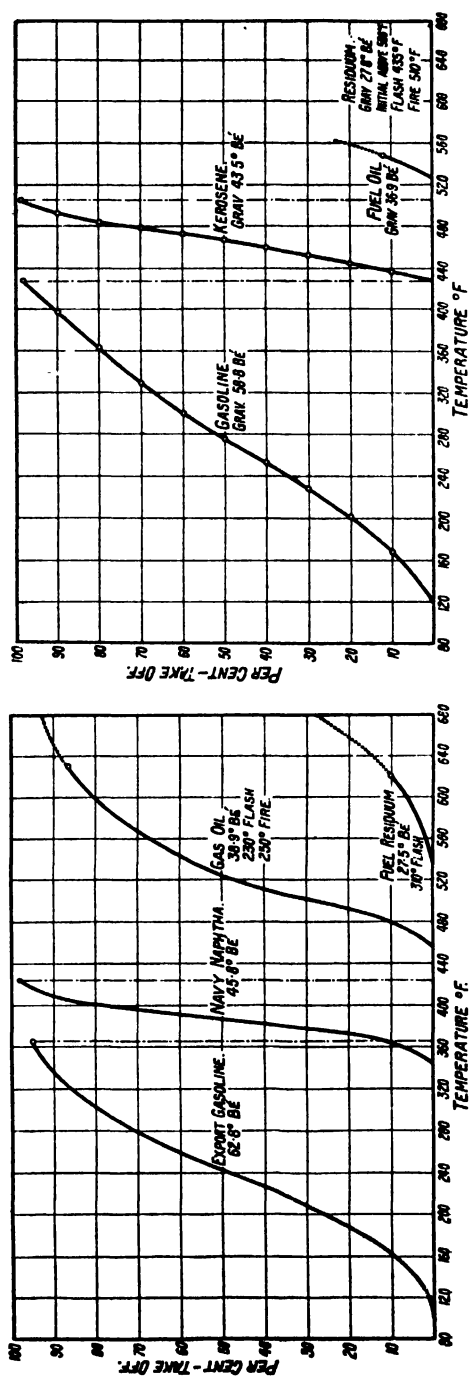


FIG. 12.—Curves showing the sharpness of cutting in a modern bubble tower.

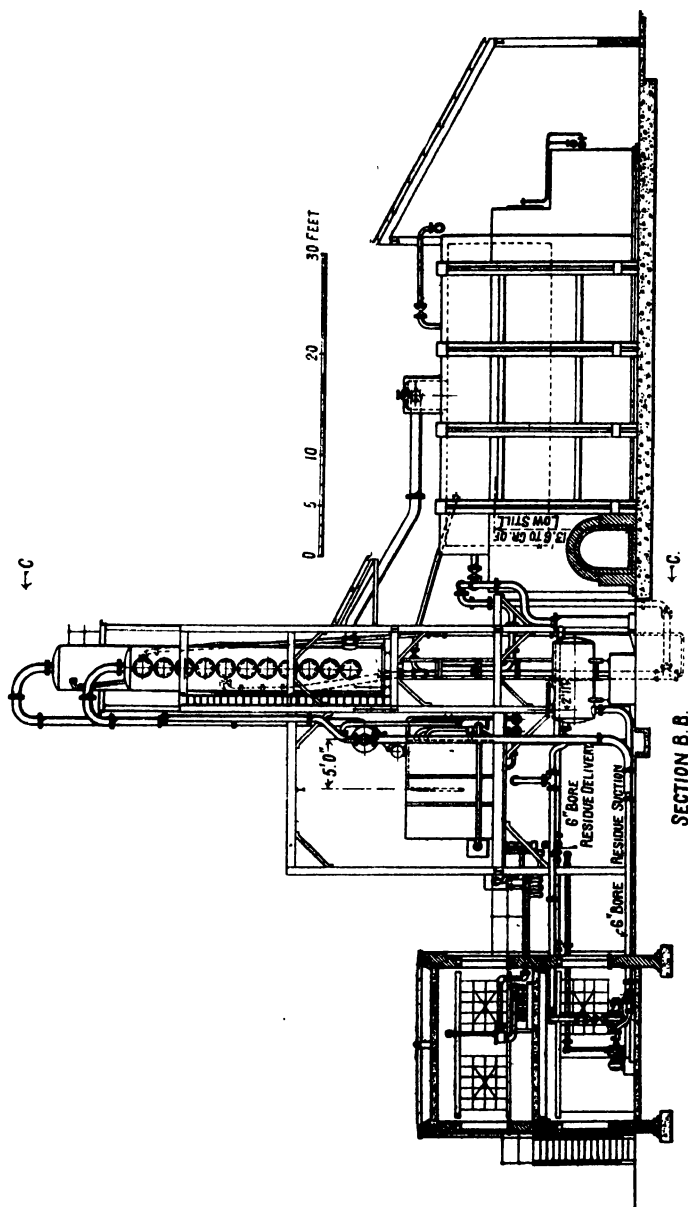


FIG. 13.—Arrangement of columns on a crude oil bench. (Badger & Co.)

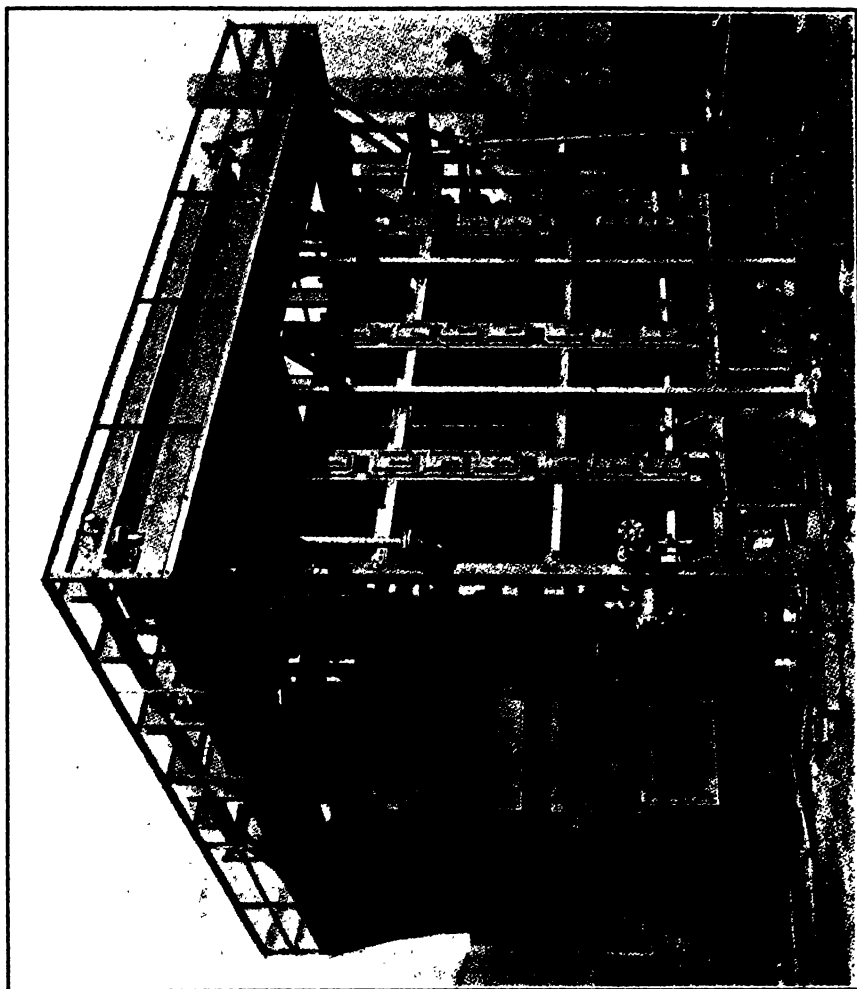


FIG. 14.—Pipe still under construction. (Power Speciality Company.)

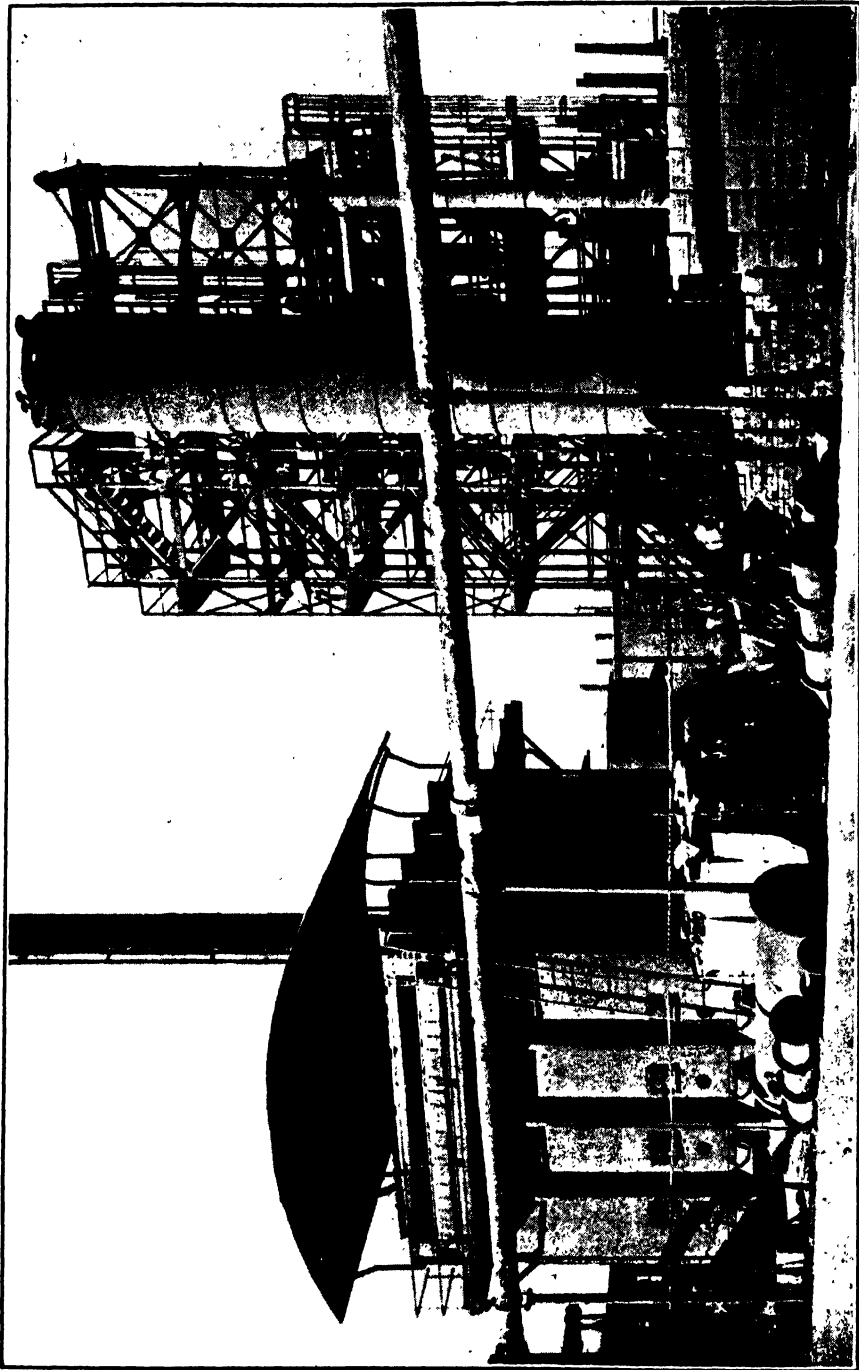


FIG. 15.—Addition of Pipe Still and Bubble Tower to a conventional Shell Still Bench.

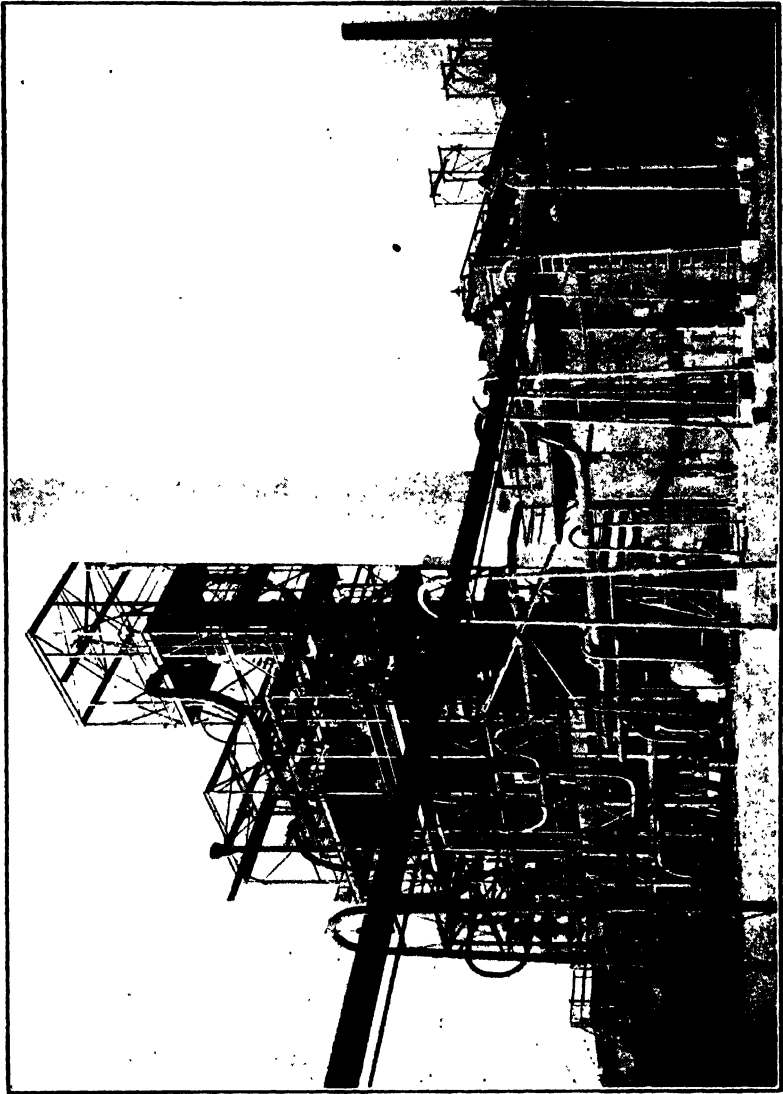


Fig. 16.—Pipe Still and Bubble Tower. (Power Speciality Company.)

reflux. The results afforded by the operation of a bubble tower are at first sight remarkable. This is shown in the following table (Primrose, *loc. cit.*) :—

Through-put of plant	...	9,200 barrels of Amarillo Crude.
Temp. tube still discharge		550°F.
<i>Overhead Gasoline—</i>		
F.B.P.		340°F.
<i>Naphtha—</i>		
I.B.P.		368°F.
Final boiling point	...	440°F.
<i>Kerosene—</i>		
I.B.P.		540°F.
Flash point		300°F.
<i>Fuel Residue—</i>		
Flash point		340°F.
I.B.P.		562°F.

It will be seen that a considerable gap exists between the end point of one fraction and the initial boiling point of the preceding fraction when determined by the standard distillation test.

Fig. 12 indicates the type of distillate produced from a crude oil that is being run to gasoline, kerosene, and a fuel residuum. The gaps between the various distillation curves are very clearly indicated.

In Fig. 15 we have an extension to an existing eight-still bench in which the preheated crude may be passed through a pipe still into a column, gasoline taken overhead, and the conventional shell stills made use of for removing kerosene, leaving a residue of fuel.

Fig. 18 shows the application of bubble towers to an existing bench of shell stills. A corresponding development is shown in Fig. 17, in which the conventional columns are shown alongside those of a newer type.

Reliable laboratory apparatus that shall closely imitate large-scale working has been described by Peters and Baker (*Ind. Eng. Chem.*, 1926, 1869), which the author can vouch for in giving excellent results. The column and condenser have been designed so as to possess this minimum liquid hold-up. Heat is supplied through windings to the flank and to the column.

Recent papers in the technical press, particularly in America, describe many typical installations of pipe still and column.

Thus Smith (*Oil and Gas Journ.*, 927, 38, 90) discusses the plant of the Pure Oil Company, in which the fractionating columns are three in number. Each is 8½ft. by 70ft., with two horizontal cylinders 16ft. long, placed at right angles to the vertical axis of the tower, one at the top to house heat exchanger and refluxing coils, and one at the bottom to contain re-boiling coils. Fresh crude passes in series through the three reflux sections, thence to the residue heat

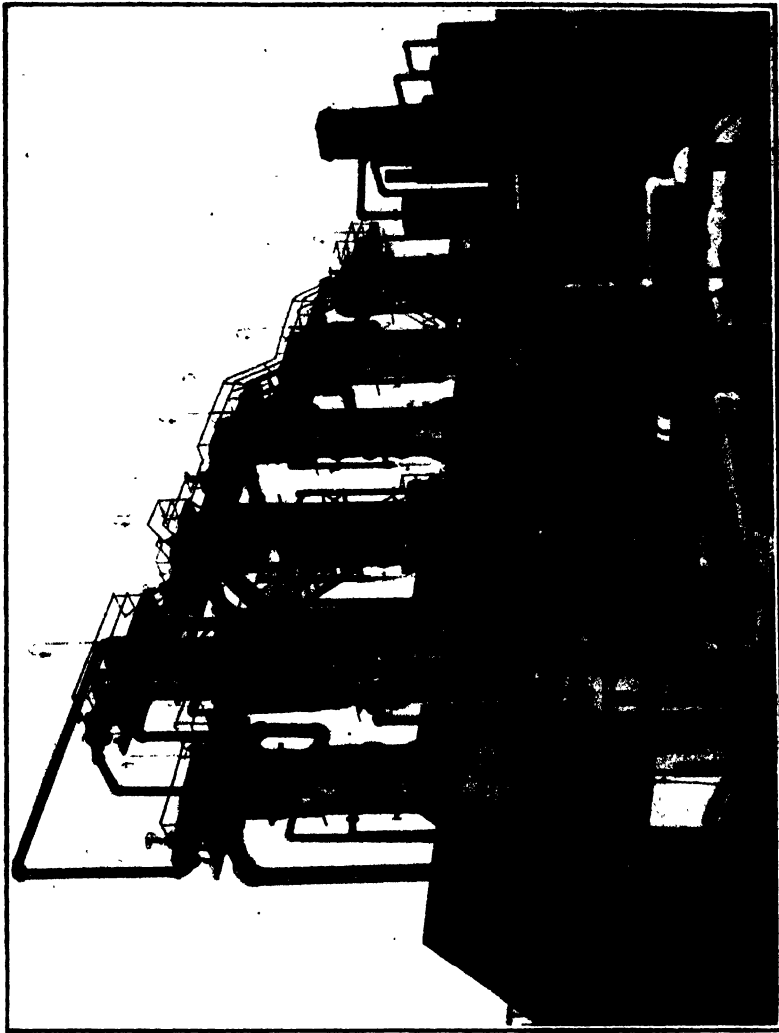


FIG. 17.—Bubble Towers adapted to Battery of Old type Shell Still. Old type column shown in background. (Badger and Sons.)

exchanger, and thence to the first heating section of the pipe still. It discharges into the lower (stripping) section of the first tower, gasoline being taken overhead whilst the residue returns to the pipe still and is vaporised. Unvaporised oil passes through the exchanger and away as fuel. The vapour enters the second tower. Gas oil and heavier oils flow from this tower through the re-boiler coils of the third column and to storage. Overhead from tower 2 may be gas oil or kerosene at option.

Miller (*Refiner*, 1927, p. 47) describes the three-tower pipe still unit of the Marland Refining Company. In this system the crude, after passing through the heat exchanger, is flashed into the first tower and gasoline is taken over-

head. The bottoms are pumped through the pipe still and flashed into the second tower, from the base of which a stripped residuum is taken. An "omnibus" distillate of gasoline, kerosene and gas oil is taken from the top of this tower to a point midway in the third tower, whence gasoline passes overhead, kerosene from a plate some distance down the tower, and stripped gas oil from the base. The same refinery operates a single-tower system from

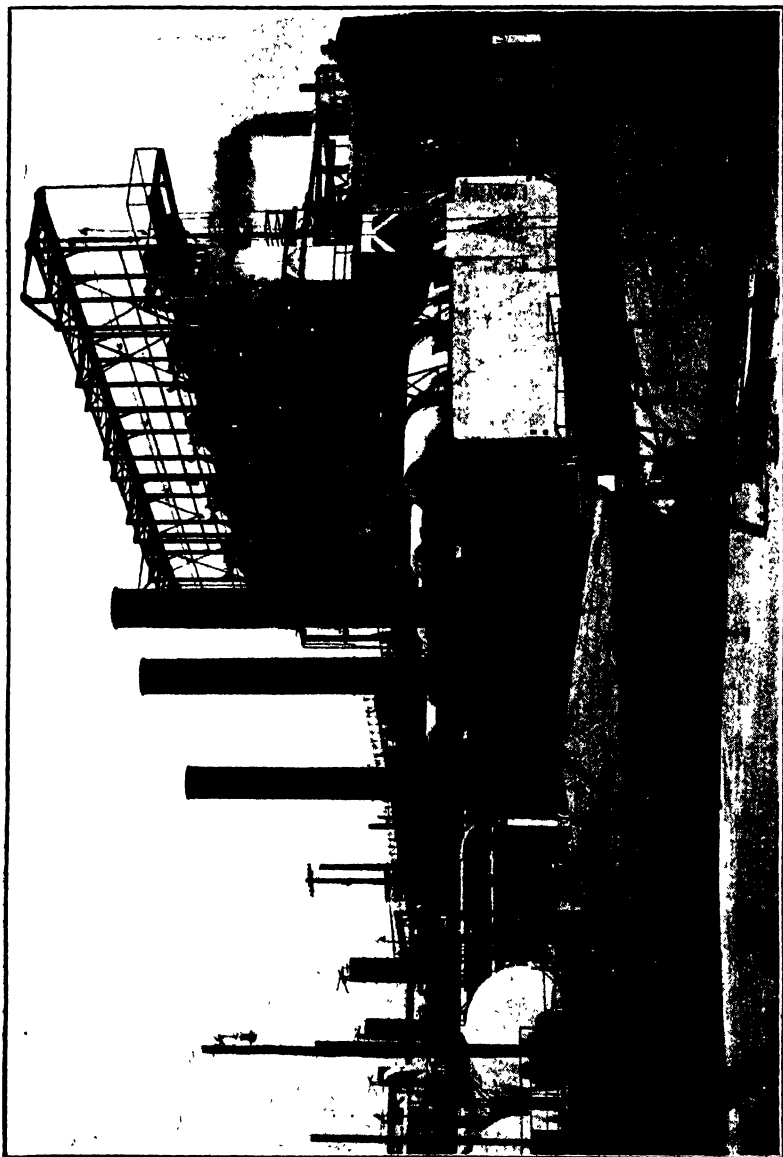


FIG. 18.—Bubble Towers adapted to a battery of Shell Stills.

which gasoline, kerosene, gas oil and residuum are removed overhead and from plates at positions down the tower.

DISTILLATION OF LUBRICATING OILS.

Only quite recently have the above methods been discussed in connection with the production of lubricating oil fractions. The bulk of the lubricating oils made to-day from petroleum is still obtained from shell stills operating under reduced pressure, and employing a very considerable amount of steam. The disadvantages of this procedure are two-fold. In the first place, oils particularly liable to thermal decomposition are held for prolonged periods in contact with metallic surfaces—in other words, every opportunity is given for profound decomposition to coke and gas, and what is far more important, the breaking down of the heavy lubricating oil molecules to systems of lower molecular weight and lower viscosity ; the second drawback is the low thermal efficiency of the operation.

Within the last year attempts have been made to apply the methods outlined above ; residue oil, for example, is passed through a pipe still at a temperature high enough for vaporisation under a high vacuum. The partial pressure of the lubricating oil fractions is brought to the lowest possible value, either by the application of vacuum in the column, or alternatively, by steam or by relatively higher pressure of less complicated components of the oil system. Two points stand out—firstly, a minute amount of decomposition product may readily be removed overhead, and, secondly, the amount of partly pyrolysed heavy hydro-carbon content is very much diminished, giving higher yields of the lubricating oil.

The author is indebted to his friend Dr. B. T. Brooks for the following description of the work of Schulze on high vacuum distillation (*Ind. Eng. Chem.* 1926, 18, 789).

DISTILLATION AT VERY LOW PRESSURE.

The advantages and markedly different results obtained by distilling lubricating oils at absolute pressure of 3 to 5 mm. as contrasted with former practice at 40mm. or higher, appears to have been first shown, and the practicability of so operating industrially first demonstrated, by Schulze.

The effect on the boiling point of lowering the absolute pressure is much more pronounced, for a given difference in pressure at very low pressures, than at moderate vacuum. A black oil distilled by Schulze illustrates this (Table XIII).

TABLE XIII—DISTILLATION OF HEAVY RESIDUUM IN VACUO.

Absolute pressure mm. Mercury	Per cent. over at 572°F. (300°C.)	Initial b.p. of fraction °F
40	30	455
25	50	437
15	68	419
5	94	364

The rapid lowering of boiling points with decrease of absolute pressure particularly at low pressures, below 40 mm., is shown by Figure 19 (Steinschneider.)

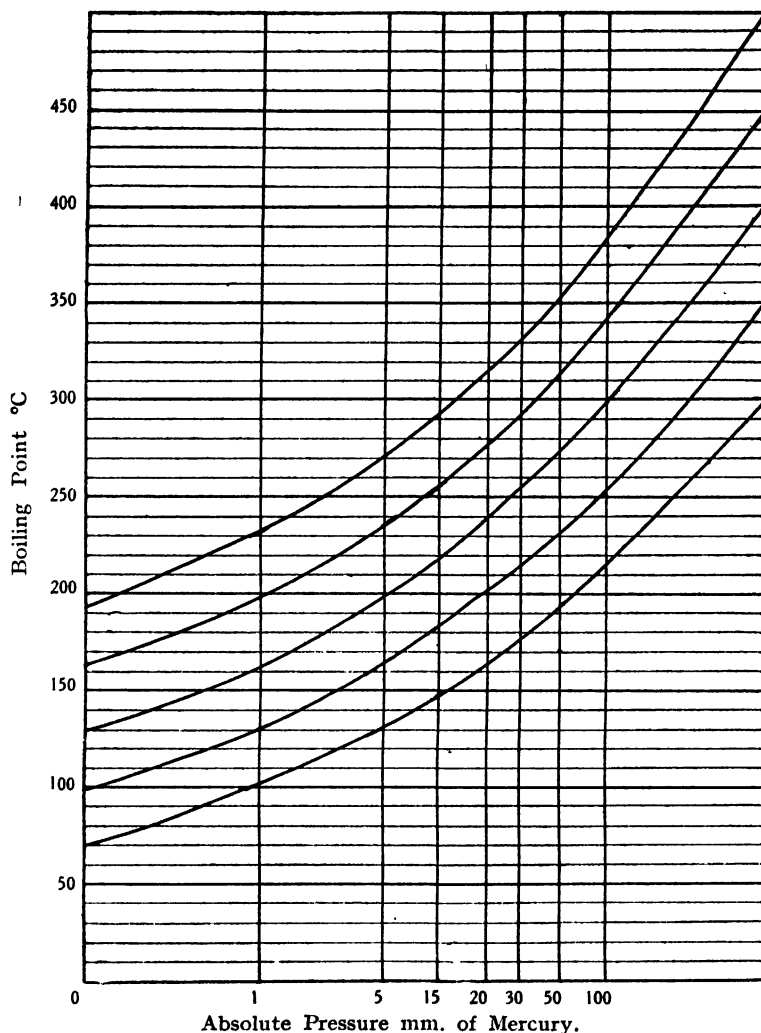


FIG. 19.—Relationship between Boiling Point and absolute Pressure of Lubricating Oils.

It is, of course, true that at absolute pressures as low as 3 mm. the oil vapours occupy a large volume, approximately 250 times the volume at atmospheric pressure, though this volume ratio is slightly reduced by the lower

distillation temperatures resulting from the low pressure. In order to provide for this large vapour volume and prevent the choking effect which would result from the usual still construction, Schulze provides as many as ten vapour outlets, 10 inches diameter each, on each 10 by 30 foot vacuum still. With this multiplicity of vapour outlets the still shows practically the same absolute pressure, within 1 mm., as shown by the manometers on the receivers and on the lines adjacent to the vacuum pumps. These outlets dip slightly away from the still, considerable condensation being effected by air cooling before passing to the water-cooled condenser, which functions as much as a cooler as a condenser. Somewhat less than 1 per cent of light, volatile, malodorous oil is taken off in a separate overhead line, leading to a separate condenser; this overhead vapour and gas line is directly connected to the vacuum pump. The bulk of the distillate flows by gravity to a series of receivers which are evacuated at the beginning of the run, the evacuation proceeding through the condensers and light overhead line to the vacuum pump. The stills and all the lines are welded throughout.

The vacuum pumps employed have been considerably improved to meet the requirements of this process. The power consumption is very small, two vacuum pumps being mounted on one base and driven by one 40 horse-



FIG. 20.—Schulze Plant, showing Stills and Vapour Pipe.

power motor. Worthington "feather" valves are a noteworthy feature of these pumps, as is the general pump design, which practically eliminates dead air space.

METHOD OF OPERATION.

High vacuum distillation is probably most advantageous in the case of wax-free oils, not only on account of the relatively low market value of such crude, but also because the absence of paraffin wax makes the production of finished lubricating oils in this way an exceedingly direct and simple process. Gasoline and kerosene, if present, should be removed in a preliminary topping distillation, and although some gas oil may be taken over in this way, care should be taken not to crack the oil. Very heavy crudes, such as heavy Smackover oil, are first dehydrated and charged directly into a vacuum still, the gas oil distilled under a moderate vacuum, and the vacuum is then raised to the usual operating pressure.

In this method of batch operation the still temperatures may reach 575° to 625°F. , depending upon the character of the oil and its resistance to cracking. The lubricating oil distillate thus obtained is emulsified with just sufficient concentrated caustic soda to combine with the naphthenic acids, and without separating these soaps the oil is re-distilled at 3 to 5 mm., cutting the fractions according to the viscosity desired. These distillates are colour stable and substantially odourless and tasteless as produced, without acid or any other treatment. In order to remove moisture and brighten these distillates, the receivers are provided with closed steam pipes by which means the oil is heated to about 200° to 225°F. , and blown with air until bright. No other refining treatment is necessary if the charging stock has not been previously damaged by cracking and the distillation has been properly carried out.

One of the characteristics of lubricating distillates produced by high-vacuum distillation is that the cuts can be made quite narrow, corresponding to a narrow range of boiling point and viscosity. In the usual practice gas oil is produced by cracking of the more valuable lubricating oils throughout the distillation period. It is the presence of these light decomposition products in very substantial proportions which gives such distillates their pronounced odour and taste, makes them discolour on exposure to air, and necessitates the use of sulphuric acid, alkali, and usually fuller's earth to put them in a marketable condition of refinement. The troubles incident to the refining of lubricating oils with acid, alkali, etc., are too well known to warrant comment. That the colour stability and other properties of the distillates produced by the Schulze process are such that no acid is required to refine them has already been noted. This colour stability is also indicated by the fact that the final distillates can be heated to 250°F. and blown with air until bright without darkening in colour. The values reported for Conradson carbon and demulsification value are also noteworthy.

STEINSCHNEIDER PLANT FOR HIGH VACUUM DISTILLATION OF LUBRICATING OILS.

THE PRINCIPLE OF THE TWO-STAGE VACUUM DISTILLATION.

The principle of the process consists in the fact that distillation is carried out in two entirely separate phases. When the raw material has been heated to the distilling temperature, the unsaturated hydrocarbons, the permanent gases and the lightest products which result therefrom are removed in the first phase; and in the second phase the distillation of the desired products, the more saturated hydrocarbons, takes place in one or in several entirely separate apparatus, the various products obtained being cooled and condensed separately in appropriate cooling apparatus.

The raw material—crude oil, topped oil, residuum, etc.—circulates continuously between the distilling apparatus and a heating apparatus, and is, each time it passes through the latter, gradually heated to its end temperature, and not by passing once only through the heating apparatus.

The lower the increase in temperature resulting from each individual pass of the liquid through the heating apparatus, the better can the separation of the decomposed products from the saturated hydrocarbons be effected, according to the difference in the boiling points, as the boiling point of the saturated constituents is higher than the boiling point of the unsaturated products which appear at the same distillation temperature.

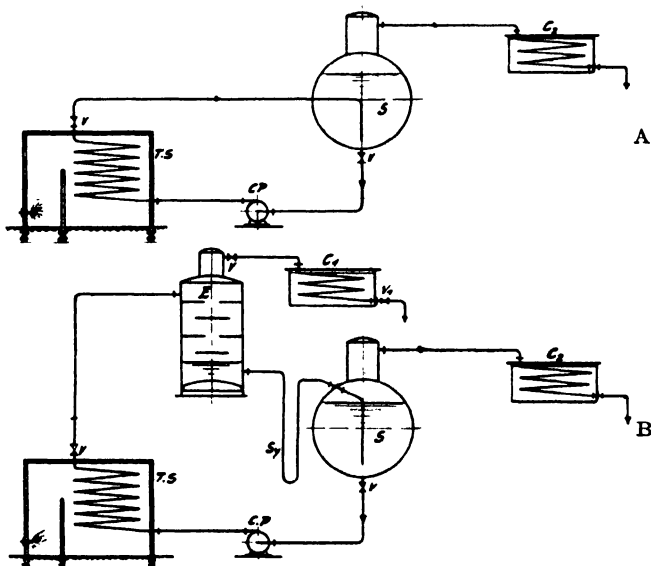


FIG. 21.—Diagram of Steinschneider Plant.

In the examples illustrated in Figure 21 the process is carried out discontinuously.

Fig. 21 A shows the fundamental principle of an ordinary distillation with a still "S," which is not direct fired and a tube still "TS" which is heated by a burner. By means of the circulation pump "CP" the liquid material is circulated between the still and the heated coil until the raw material is distilled down to the concentration desired.

Fig. 21 B shows the apparatus of the Two-stage Distillation.

The liquid material circulates between the still "S," the heater coil "TS" and the evaporator "E," so that before entering the still "S" the liquid material passes the evaporator "E." The pressure in the evaporator "E" is so high, that only the permanent gases, the lightest fractions and the products of decomposition formed by heating, escape due to their lower boiling point. The liquid raw material, which is thus stripped of the decomposed products

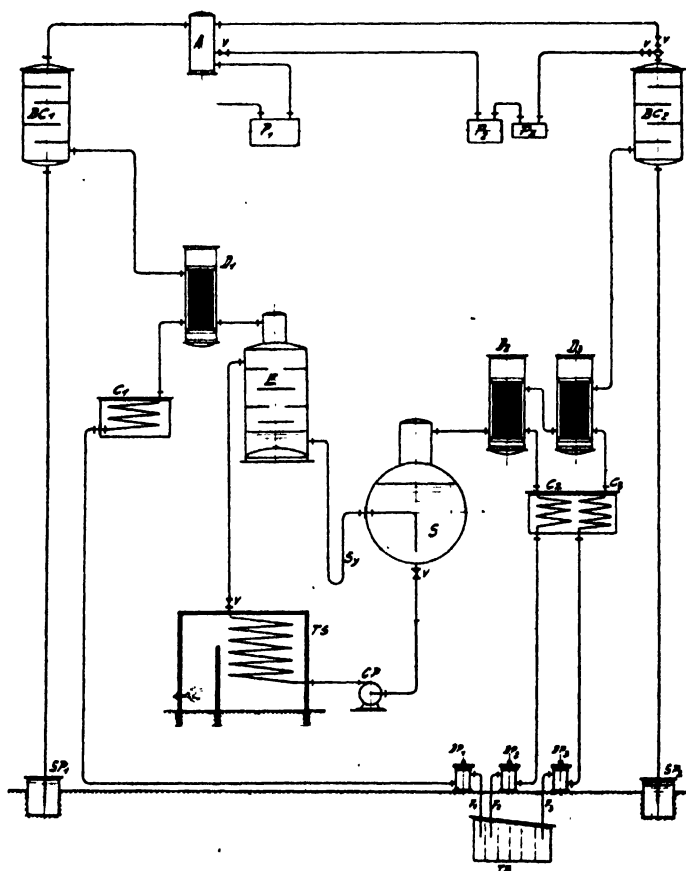


FIG. 22.—Diagram of Steinschneider Plant.

in Evaporation chamber "E," then passes through the syphon "Sy" to the distilling chamber "S," which is not direct fired and in which the evaporation of the heavier fractions, i.e., the desired products is effected by the operation of variable pressure. The pressure difference between the apparatus "E" and "S" is maintained by throttling the valve "V," and the flow of the liquid material from "E" to "S" is regulated automatically by syphon "Sy."

If working under vacuum by means of two stage or three stage air pump the evaporator "E" is connected with the air pump which produces the higher absolute pressure, and the still "S" is connected to the air pump which produces the lowest absolute pressure.

Fig. 22 is the scheme of a distilling plant similar to that of Fig. 21 B, but operating under vacuum.

The arrangement is made so universal that the plant can work either under an absolute pressure of 5 mm. and without steam, or at a higher absolute pressure and with steam, so that steam can be injected both into the evaporator and into the still.

The plant is equipped with two barometric condensers, one for the evaporator "E" and another one for the still "S." If steam is used in "E" and "S" water is injected for cooling in both barometric condensers. In this case the two-stage air pump "P₂" "P₃" is cut out, and the incondensable gases are sucked out only by air pump "P₃" of the two barometric condensers.

When operating without steam, the two-stage air pump "P₂ P₃" sucks the incondensable dry gases out of the barometric condenser "BC₂," whereas the air pump "P₂" draws off the incondensable gases from the barometric condenser "BC₁."

When steam is injected into the evaporator "E" cooling water only is injected into the barometric condenser "BC₁."

The exhaust of the air pump "P₂" is connected with the collector "A" from which the air pump "P₁" is drawing. By these means the two-stage air pump works like a three-stage pump. When distilling without steam the following absolute pressures were produced easily: in evaporator "E" an absolute pressure of 25-50 mm., in the still "S" an absolute pressure of 4-5 mm. Hg. But by distilling the same material with injection of steam and with an absolute pressure of about 50 mm. Hg. a difference in the quality of the distillates could not be found.

The arrangement in this Figure renders it possible to operate at any time with steam and a vacuum of about 30 mm., or without steam and a vacuum down to 4 mm. Hg. The air pump "P₂ P₃" for distilling with a vacuum lower than 25 mm. can be installed at any later time if practical tests show really better results by this extreme vacuum.

NOTES ON BOOKS.

A GLOSSARY OF ENGLISH FURNITURE OF THE HISTORIC PERIODS. By J. Penderel-Brodhurst and E. J. Layton. London: John Murray. 6s.

It seems natural to some people to believe in progress in the abstract. But when one comes down to certain concrete cases it is very hard to see how, beyond a point, any progress is, in fact, possible. The most eminent and creative typographers of the day have no hesitation in telling us that the type faces of Caslon and Baskerville, Fournier and Didot, can be varied a little but not improved upon. And though our connoisseurs in furniture may not have declared themselves in a similar way, it strikes one as unreasonable to look forward to any remarkable advance in furniture design. So long as human proportions do not alter, so long as legs and arms need the accommodation that they do, and have done for many centuries, it is unlikely that anything better than the work of Adam, Chippendale, Hepplewhite and Sheraton will come on the market.

Modern furniture has its enthusiasts; some of it is excellently well in keeping with modern architecture. But it is seldom that a modern piece can, so to speak, stand on its own legs, or make an agreeable impression out of its context.

Messrs. Penderel-Brodhurst and Layton have produced a valuable little book which makes quite good reading, for it is full of information: little biographies, anecdotes, etc., as well as plain definitions. We learn from it that ash "has a peculiar and unusual lateral grain known as 'fiddle-back' or 'ram's-horn'"; that Riesener who signed the "Bureau du Roi," had married the widow of Oeben, his master; that glass mirrors were almost exclusively made in Venice from the beginning of the fourteenth to the beginning of the seventeenth century.

Authors are not quite unanimous in their systems of dividing up the periods of English furniture. An interesting method was adopted by Mr. Percy Macquoid, who divided the whole period 1500-1800 into the Age of Oak, 1500-1660; the Age of Walnut, 1660-1720; the Age of Mahogany, 1720-1770; and the Age of Satinwood, or the Composite Age, 1770-1820. More detailed sub-divisions are given.

To make so much of a mere glossary needed the knowledge and experience which Messrs. Penderel-Brodhurst and Layton are well known to possess.

INTRODUCTORY HANDBOOK TO THE STYLES OF ENGLISH ARCHITECTURE. By Arthur Stratton. London: B. T. Batsford, Ltd. 1s.

There are two subjects, omitted from school curricula, which interest more boys and girls than one might think likely. These subjects are philosophy and art history. Masters often realise that their pupils are charmed by old churches, and in a private way discuss with them the arch and the column; perhaps take them on an expedition to look at some old church in the neighbourhood.

Messrs. Batsford are now publishing a series of comparative diagrams to illustrate the styles of English architecture, and as companions to these Mr. Stratton has written his introductory handbooks. Part I deals with the Middle Ages from Saxon times to the fifteenth century. It strikes one as a good basis for lectures on the elements of architecture, technical and historical, and the diagrams to which it forms the accompaniment are well chosen and easy to understand.

The glossary and index to illustrations printed on the cover of the handbook are useful.

P.B.

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PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES

SCIENTIFIC FOUNDATIONS OF THE REFINING OF PETROLEUM.

By A. E. DUNSTAN, D.Sc. (London), F.I.C., F.C.S.

Vice-President and Editor of the Transactions of the Institution of Petroleum
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III.

THE REFINING OF PETROLEUM DISTILLATES.

(Delivered January, 1928.)

SODA WASHING.

In the case of a crude oil containing sulphur the crude distillates from the stills possess a peculiarly unpleasant "sour" odour, due to sulphur compounds present in comparatively large amount.* This in itself does not detract from the value of the benzine or kerosene as fuels for internal combustion engines; nevertheless, since the public expects to buy a petrol of unobjectionable odour, it is absolutely necessary to sweeten the distillate before placing it on the market. There are two distinct ways in which this may be accomplished; (1) by converting the evil smelling sulphur compounds into other compounds which are either odourless or sweet-smelling without actually decreasing the sulphur content of the spirit to any marked extent. (2) by removing the sulphur derivatives more or less completely.

* It must be remembered that a sulphur content of 0.20% corresponds with nearly 0.75% sulphur compound in a naptha distillate.

Although benzine refined by the second method is of slightly superior odour, the first procedure gives a product which is quite acceptable, in fact only distinguishable with difficulty from the fully desulphurised material. The second scheme of treatment entails a heavier refining treatment, and, therefore, a greater expenditure of time and material.

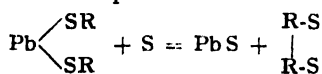
The desirability of refining by the first method is therefore clearly evident. Actually a combination of both is now practised, but there is a growing tendency towards the first scheme.

The sulphur occurs in the distillates in many different forms, which are of different types and which react towards refining agents in different ways. It is therefore necessary to adopt the treatment to the various types of sulphur compounds present.

A small proportion of the sulphur occurs in the free or elementary state[‡]; a comparatively large proportion is present as hydrogen sulphide, H_2S , whilst the remainder is in the form of organic derivatives of sulphur. The last are divisible into two classes; (1) acidic, a property shared with hydrogen sulphide and due to the presence of the $-SH$ group, and (2) neutral. The first includes mercaptans, which together with the hydrogen sulphide, are mainly responsible for the unpleasant odour of the unrefined distillates and for the positive reaction of the well known "doctor" test*. The second class includes the organic sulphides and disulphides. Later (see section on hypochlorite washing) it will be shown that hydrogen sulphide, mercaptans, sulphides, and disulphides are all oxidisable by means of aqueous alkali hypochlorite solutions, and that a spirit containing these substances so treated is rendered completely sweet and pleasant in odour. But whereas the products of oxidation of the organic sulphur compounds are either removed completely by that treatment, or remain in the oil as perfectly harmless and inoffensive compounds, hydrogen sulphide is oxidised to free sulphur, the presence of which in a light distillate cannot on any account be tolerated; in benzine it is highly corrosive to metals, it causes kerosene to burn badly and to film the lamp glass, and in white spirit,

[‡]Elemental sulphur occurs chiefly through the aerial oxidation of the hydrogen sulphide that accompanies the distillate, and which is produced by the thermal decomposition of sulphur compounds in the crude oil.

* The "doctor" test is employed to find whether a distillate is sour, *i.e.*, contains hydrogen sulphide or mercaptans. The reagent is an aqueous solution of sodium plumbite $NaPbO_2$. When shaken with a distillate containing hydrogen sulphide a black precipitate is at once formed. Mercaptans, when no hydrogen sulphide is present, produce a yellow or brown coloration of the oil owing to the formation of lead mercaptides. If much mercaptan is present a precipitate may form, but as the lead salts of the higher mercaptans are spirit soluble no precipitation occurs with heavier distillates. The addition of free sulphur renders the test for mercaptans more sensitive, as minute traces of lead mercaptides are converted by it into black lead sulphide. This reaction can be expressed as follows:—



The American method of refining by means of plumbite is based upon this reaction, any reduction of sulphur being due to adsorption of sulphur compounds on the precipitated sulphide.

which is used for dry cleaning, it affords hydrogen sulphide on redistillation and thus the recovered solvent is rendered foul. It is therefore evident that the complete removal of hydrogen sulphide must be effected before the light distillate is treated with an oxidising agent such as an alkaline hypochlorite.

Fortunately this is readily accomplished. Hydrogen sulphide H_2S is a dibasic acid. By the action of an alkali hydroxide solution either or both of the hydrogen atoms may be replaced by the alkali metal (such as sodium), with the formation of the metallic sulphide. The latter remains in the aqueous wash-liquor; the solution is quite stable and is only decomposed by the action of a stronger acid. This property is shared, qualitatively, with the acidic organic sulphur derivatives, the mercaptans ($R.SH$, where R is a hydrocarbon radicle). But whereas hydrogen sulphide is dibasic and is a comparatively strong acid, the mercaptans are monobasic and are only very weakly acidic. The sodium mercaptides are in fact readily hydrolysed by water; in other words the reaction by which they are formed is reversible and is represented by the equation:



Consequently the removal of a mercaptan from petroleum by agitation with aqueous alkali is never complete; a balance is eventually attained between the concentration of mercaptan (as free mercaptan) in the oil and the concentration of mercaptan (present as alkali mercaptide) in the aqueous solution. Moreover the acidity of the mercaptans (the ease of replacement of the acidic hydrogen atoms by a metal) rapidly falls off as the molecular weight of the hydrocarbon radicle, R , is increased. This is well brought out in the following table.

TABLE XIV.

Compound.	Boiling Point.	Percentage removed from petroleum solution by the same quantity of soda solution under identical conditions.
Hydrogen sulphide H_2S (gas)		100
Ethyl mercaptan, $C_2H_5.SH$	39°C	97.1
<i>n</i> -Propyl „ $C_3H_7.SH$	68	88.8
<i>iso</i> -Propyl „ $C_3H_7.SH$	59	87.2
<i>n</i> -Butyl „ $C_4H_9.SH$	98	63.2
<i>iso</i> -Butyl „ $C_4H_9.SH$	88	62.8
<i>iso</i> -Amyl „ $C_5H_{11}SH$	118	33.0

When discussing the difficulty of effecting mercaptan removal from even a light distillate by soda washing this table is highly instructive. Consider the highest mercaptan examined, *isoamyl* mercaptan. It has a boiling point of 118°C and under the conditions of the experiment (which are comparable with the usual works practice when batch-washing) only 33% was removed. At 118° roughly 40% of naphtha distils over, so that there is 60% of higher boiling material. If the mercaptans were evenly distributed there would also be 60% of mercaptans even less readily removable by soda than *isoamyl* mercaptan. The actual figure is probably even higher, as is well shown by figures giving the distribution of sulphur in a crude oil. It follows that the

TABLE XV.

Distribution of sulphur in a Persian crude oil.

Fractions.				S. per cent.
Benzine.	...	...	...	0.08
Kerosene	...	...	...	0.15
Gas Oil	...	...	...	0.75
Heavy Oil and Paraffin	...	...	...	1.50
Pitch	...	...	...	3.40

complete removal of acidic bodies by soda washing alone is almost impossible ; in the batch process, the attainment of equilibrium between mercaptan in the oil and mercaptan in the soda makes complete removal absolutely impossible. Nevertheless, even by the batch process, hydrogen sulphide can be entirely eliminated by soda-washing ; stress must be laid on this in view of the necessity for removing hydrogen sulphide prior to any subsequent process involving oxidation.

With efficient mixing, the balance represented by the reversible equation $\text{RSH} + \text{NaOH} \rightleftharpoons \text{RSNa} + \text{H}_2\text{O}$ is rapidly attained. A multiplicity of washes is, therefore, of advantage ; the even greater benefit of the continuous counter-current method, in soda-washing, is at once evident. Furthermore, where the counter-current system is employed, the soda consumption is considerably reduced.

There is, however, another property of the .SH group which has an important bearing on soda washing. Compounds containing this group readily undergo oxidation ; thus hydrogen sulphide is oxidised to elementary sulphur, and mercaptans to organic disulphides. Oxidation may be brought about by atmospheric oxygen or by free sulphur ; in the oxidation of mercaptans the last agent is particularly effective in the presence of aqueous soda. Free sulphur can only be removed from the oil with difficulty. Since, therefore, it is produced from hydrogen sulphide with great readiness by aerial oxidation it is of the highest importance that unrefined light distillates should be soda-washed as soon after production as possible, and that until this is done contact

with the air should be avoided. The distillates are therefore soda washed at the worm ends.

The aerial oxidation of mercaptans is probably slight, but oxidation undoubtedly occurs in the soda solution during soda-washing through the agency of alkali polysulphides. These are formed from elementary sulphur in the unrefined oil and sodium sulphide (derived from hydrogen sulphide). The products of oxidation, disulphides, are neutral substances which, being insoluble in soda, return to the petroleum during the soda treatment. If desulphurisation is aimed at, this return of sulphur to the oil as disulphide entails a heavier subsequent treatment of gasoline and kerosene following redistillation. The formation of disulphides depends, as pointed out, on the elementary sulphur in the unrefined distillate. There is, then, an additional reason for avoiding, as far as possible, the production of free sulphur, by aerial oxidation.

A comparison of the boiling points of the mercaptans and of the disulphides derived from them shows how distillation following soda-washing reduces the sulphur content of the gasoline.

Owing to their comparatively high boiling points the disulphides are left in the residue, as they are outside the boiling range of the distillate, although the parent mercaptans fall well within that range.

TABLE XVI.

Mercaptan.	Boiling Point.	Boiling Point of Disulphide.
Ethyl ...	39°C. ...	152°C.
<i>iso</i> Propyl ...	59 ...	175
<i>iso</i> Butyl ...	88 ...	220

The "spent soda" leaving the washers is yellow in colour and has an odour of mercaptans. Owing to the presence of alkali polysulphides it is difficult to reclaim, but on being boiled the sodium mercaptides undergo hydrolysis and some saving can thus be effected.

Distillation of the spent soda shows it to be an excellent source of the mercaptans present in the unrefined distillate; the oil which separated from the distillate contained mercaptans and disulphides. The latter are produced in large amount by oxidation of the sodium mercaptides by sodium polysulphides, the reaction, normally rather sluggish, being greatly accelerated at the high temperature of distillation. Fractional distillation of the mercaptans and of the disulphides, followed by chemical examination of the fractions obtained, indicated that the following substances are present in light distillates derived from Persian crude oil.

TABLE XVII.

<i>Mercaptans.</i>			
<i>iso</i> Propyl mercaptan	...	b.p.	59°
<i>iso</i> Butyl	„	...	88°
<i>iso</i> amyl	„	...	115 - 120°

Disulphides.

Diethyl disulphide	...	b.p. 152°
Diisopropyl disulphide	...	175°
Diisobutyl disulphide	...	220°

From the presence of diethyl disulphide it may be inferred that ethyl mercaptan is present in the unrefined distillate. Owing to their relatively low acidity the quantity of the higher mercaptans in the soda was too small for identification.

THE HYPOCHLORITE PROCESS.

HISTORICAL.

The refining of petroleum distillates by the use of chlorine in various forms is not new in theory, although its successful application is comparatively recent. Thus Watson Smith (E.P. 2025/1880) passed chlorine gas into petrol oils and distilled off a spirit of "faint and agreeable odour"; he did not, however, give any analysis of the refined gasoline for chlorine content. S. E. and E. E. Johnson (E.P. 5255/1875) prescribed very similar treatment and completed the refining by filtration through charcoal. Processes in which chlorine is employed depend entirely upon the oxidation of most of the oil-soluble sulphur compounds to water-soluble compounds; this results in a more or less complete desulphurisation of the oil. The oxidising properties of chlorine are retained if the gas is dissolved in water, the resulting solution containing free hydrochlorous acid; this form of the reagent is naturally more convenient in use than the gas itself. The use of chlorine water shares, however, the disadvantages involved in the use of chlorine gas; the treatment inevitably brings about chlorination, especially of the heavier constituents of the oil. Nevertheless a perfectly good product may be obtained by redistilling the chlorine-treated oil, the chlorinated bodies in the residual light kerosene being easily removed by adsorption on bauxite. This process, involving treatment of a primary distillate with subsequent wasteful re-running, has long been discontinued. The removal of chlorinated hydrocarbons from either petrol or burning oil, should they be formed, is obviously essential. It is better, however, to avoid chlorination in the first place, and the modern use of hypochlorite may be said to have commenced with the achievement of this end (E.P. 139, 223/18; 184, 281/21; 204, 078/22). A finished and marketable spirit is now produced by washing the gasoline (either straight-cut or from redistillation of soda-washed naphtha) with an aqueous alkaline or alkaline earth hypochlorite solution under controlled conditions, this process being followed by a small soda wash to remove traces of hypochlorous acid, etc., dissolved in the oil. It is essential that the hypochlorite solution should contain sufficient free alkali to stabilise it, but insufficient to retard appreciably the interaction of the hypochlorite and the objectionable sulphur compounds of the oil.

The reason for this was obscure when the controlled hypochlorite process was evolved ; much work on this subject has since been carried out with illuminating results (v.i).

PREPARATION OF HYPOCHLORITE SOLUTIONS.

Both calcium and sodium hypochlorite solutions are readily prepared. The sodium hypochlorite originally employed in the process was manufactured by the electrolysis of brine, the current density being adjusted to give, simultaneously, chlorine and the requisite quantity of free alkali ; 0.2—0.3 N solutions were easily prepared in this way. Later it was found more economical to purchase chlorine in 10 ton tank cars and pass the gas into 10 per cent. caustic soda solution until the required concentrations of hypochlorite and of free alkali are attained. At first it would appear difficult to regulate the alkali content as the later stage of the absorption is proceeding ; nevertheless the men engaged in this operation soon become exceedingly proficient. Still later, sodium hypochlorite was replaced by calcium hypochlorite, which is now in use. Chlorine is passed into well-agitated milk of lime ; the appearance of a pink coloration, due to the presence of traces of manganese salts which become oxidised to permanganates, gives warning when the absorption is nearing completion. The freshly prepared calcium hypochlorite solution is roughly 2N. After settling it is diluted to a working strength of 0.2-0.3 N, or even lower, the free alkali content of the diluted reagent is equivalent to 0.5—1.0 grams caustic soda per litre. At Abadan, calcium hypochlorite solution is prepared from bleaching powder. Clearly the dilution of strong hypochlorite solution results in an equivalent diminution in free alkalinity.

APPLICATION.

The hypochlorite treatment is always given after a preliminary soda-wash, which removes acidic sulphur compounds and effects a considerable economy in chlorine. Originally crude naphtha was soda-washed, hypochlorite treated, and redistilled. The distillate, after a small soda-wash, was finished ; the residue was, however, dark in colour, and required acid treatment before it could be decolorised and desulphurised by means of bauxite. Later the once-run distillate was soda-washed and redistilled, only the spirit being hypochlorited. The product was pleasant in odour and was marketable after receiving a small final soda-wash ; the chlorine content was approximately 0.01%. The residual kerosene, which had not been hypochlorite treated, was of much better colour and required a smaller acid treatment. This procedure is still in use to some extent, but is being modified since benzines, white spirit and kerosene are being cut directly from the crude oil by means of efficient fractionating columns. Benzine distillates, after preliminary soda-washing, receive a hypochlorite treatment followed by a soda wash, and are then fully refined.

With an initial sulphur content of 0.08 between 3 and 5 lbs. of chlorine per ton of spirit suffices to give a sweet product.

METHOD OF AGITATION.

Hypochlorite may be applied either by the batch process or continuously. The proportion of hypochlorite solution required varies with strength of solution (which is generally 0.3 N or less), sulphur content of distillate, and the degree of refining desired. In the batch process the time of agitation (which obviously depends upon the efficiency of the mixing) is usually about 30 minutes. The first hypochlorite wash is followed by a second of similar duration, and this in turn by washes with water and a small quantity of soda. The spent hypochlorite, containing dissolved oxidised sulphur compounds together with calcium chloride, is run to waste. Batch agitation is being successfully replaced by continuous washing which has proved highly efficient. The flow of hypochlorite is so regulated that the spirit is refined to the desired degree whilst the effluent aqueous reagent is completely spent.

DEGREE OF REFINING AND THE PERMANGANATE TEST.

The degree to which refining is carried depends on market requirements. Originally, refining was continued until a standard quantity of standard potassium permanganate solution retained its colour after 10 minutes agitation with a standard volume of spirit. This corresponded with a sulphur content of 0.01-0.02%. This is very complete refining and scarcely necessary for every day needs. Later the hypochlorite treatment was reduced and simultaneously a new permanganate test devised. A fixed volume of spirit was shaken for a given time with a standard N/10 permanganate solution in the presence of sulphuric acid, and the excess of permanganate determined; the volume of permanganate destroyed by the spirit had to fall within a specified quantity. The permanganate absorbed gives a measure of the organically combined sulphur remaining in the refined distillate. This will include all types of organic sulphur compound—mercaptans, sulphides, and disulphides.

MECHANISM OF THE HYPOCHLORITE PROCESS. (Birch & Norris, *Journ. Chem. Soc.*, 1925, **127**, 898 and *ibid* 1925, **127**, 1934.)

In order to investigate the action of hypochlorite on the sulphur compounds of Persian light distillates, a study was made of the action of aqueous sodium hypochlorite on representative sulphur compounds of the types likely to be present. By choosing substances of similar type but of differing molecular weight, the effect of that factor on velocity of reaction was examined. There being no definite information available concerning the products of interaction of hypochlorites and sulphur compounds, the first stage of the investigation dealt with the examination and identification of the products, which are tabulated below:—

TABLE XVIII.

Sulphur Compound.	Reaction Products.		Insoluble. Sulphur
	Sol. in Oil.	Sol. in Water.	
Hydrogen sulphide.	(Sulphur).	Sulphuric acid.	—
Ethyl mercaptan.	Ethyl disulphide.	" (trace).	
Isopropyl mercaptan.	Isopropyl disulphide.	Ethane sulphonie acid.	—
		Sulphuric acid (trace)	
Isobutyl mercaptan.	Isobutyl disulphide.	Isopropane sulphonie acid.	—
		Sulphuric acid (trace)	
		Isobutane Sulphuric acid.	
Ethyl sulphide.		Ethyl sulphone.	—
n-propyl sulphide.	(n-propyl sulphone)	n-propyl sulphone.	—
Isobutyl sulphide.	← isobutyl sulphone →		—
Isoamyl sulphide.	Isoamyl sulphone.	(isoamyl sulphone)	—
Pentamethylene sulphide	← sulphone →		
diethyl disulphide		ethane sulphonie acid	
Isoamyl sulfoxide	Isoamyl sulphone.	sulphuric acid.	
diethyl sulphone		(isoamyl sulphone).	
thiophene.		no action.	

The results may be summarised as follows :

(1) Whereas hydrogen sulphide, mercaptans, and disulphides all react to give at least some acid products, no acid products are formed from sulphides or sulfoxides.

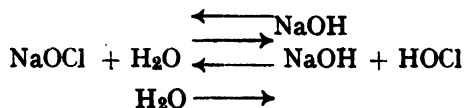
(2) Thiophenes and sulphones do not react under the conditions employed.

(3) Increase in molecular weight of the sulphur compound (*a*) decreases the rate of oxidation—diisoamyl disulphide hardly reacts at all (*b*) decreases the solubility of the oxidation products, which become increasingly soluble in the oil layer.

(4) Increase in the free alkali content of the hypochlorite decreases the rate of reaction considerably, and conversely. This fact had been known for some time from works practice.

(5) Dilution of the hypochlorite increases the rate of reaction.

The first point is of great importance, because the acid products neutralise the free alkali of the reagent as they are formed, and thus progressively render the hypochlorite more reactive. Consequently, if insufficient alkali is originally present the aqueous solution may actually become acid, when there will be a tendency for chlorination to occur. As it was confirmed that the addition of free alkali stabilises the hypochlorite, the explanation of the narrow limits for alkali content necessary in large scale operations becomes clear. The retarding influence of free alkali, and the accelerating effect of dilution are convincingly explained, on the assumption that the active oxidising agent is not sodium hypochlorite, but free hypochlorous acid produced by reversible hydrolysis :



On this view, added sodium hydroxide will displace the equilibrium to the left, dilution will move it to the right, and, in accordance with the observed facts, the solution will be stabilised or accelerated, respectively.

SULPHIDES.

In considering the oxidation of sulphur compounds by hypochlorite it is convenient to commence with the action of sodium hypochlorite on sulphides. The latter (provided the hypochlorite is sufficiently active when a higher member of the sulphide series is being dealt with) are quantitatively oxidised to sulphones. No traces of any intermediate compounds appear to be formed and hypochlorite is without further action on the resulting sulphones. Four atoms of available chlorine are absorbed for each sulphur atom oxidised. The alkalinity of the hypochlorite does not change appreciably during the reaction. The lower sulphones are more soluble in water than in light petroleum and are found chiefly in the spent aqueous reagent. With increase in molecular weight the resulting sulphone tends to remain in the oil being more soluble therein than in water; the sulphur content of the oil therefore remains unaltered. Thus although diethyl sulphone is practically insoluble in petroleum and readily soluble in water, the reverse is true of *diiso*-amyl sulphone. Sulphones are very high boiling and are left as residues if spirit containing them is distilled. Sulphones of intermediate molecular weight, e.g. dipropyl and *diisobutyl* sulphones, can be gradually removed from the petroleum layer by water washing.

The rate of oxidation of sulphides, particularly the lower members, is only slightly affected by the alkalinity of the hypochlorite. The effect is very small, large quantities of free alkali being required to prevent the oxidation occurring within a comparatively few minutes.

DISULPHIDES.

The primary oxidation products from a disulphide, unlike those from a sulphide, are acidic, i.e., the sulphonic acid together with a smaller quantity of sulphuric acid; these appear in the aqueous layer as their sodium salts. The formation of sulphuric acid is surprising; since sulphonic acids are not further attacked, it is formed directly from the disulphide. The gradual neutralisation of the free alkali by the acidic products make it necessary, in describing the effect of alkalinity on the reaction, to distinguish two somewhat different cases. (1) The free alkali present is more than equivalent to the total possible acid products; the reagent will always remain alkaline. (2) The free alkali is less than equivalent to the total possible acid products; if the reaction is continued long enough the reagent will become acidic. The reaction under the first condition may be described as the normal one; plotting atoms of available chlorine absorbed per atom of sulphur originally present as diethyl disulphide against time, curves are obtained of which (i) for a strongly alkaline

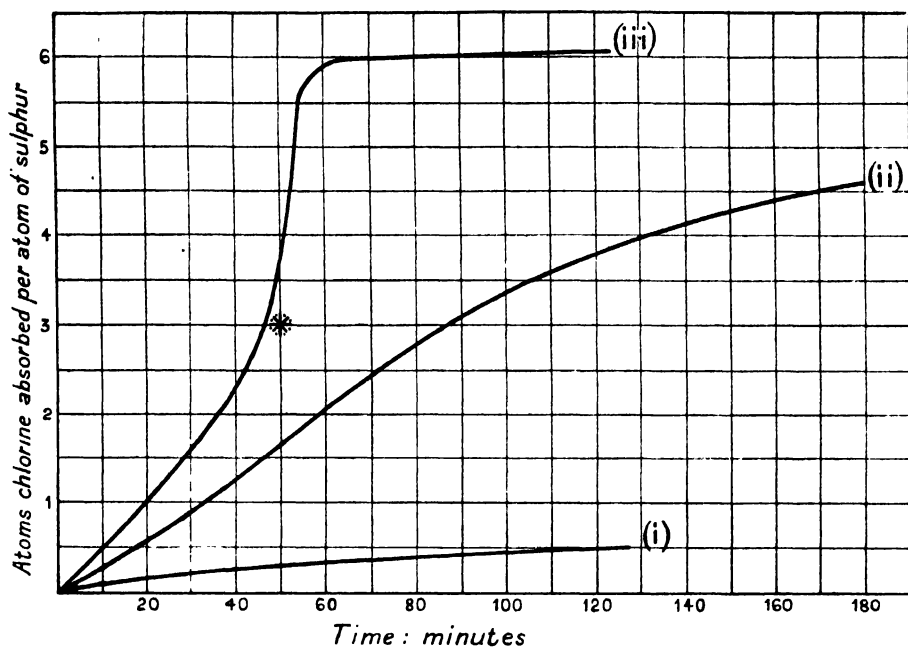


FIG. 23—Reaction between Hypochlorite and Alkyl Disulphides.

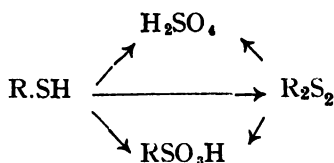
and (ii) for a weakly alkaline solution are typical. The influence of the added alkali hydroxide is very marked. If, however, the alkalinity of the reagent is so chosen that it falls into the second class, the additional complication causes the absorption-time curve to assume quite a different form (iii). The initial part of the reaction takes the normal course until the acidic primary products have completely neutralised the free alkali present; at that point (*) there occurs a very rapid absorption of available chlorine which continues until the sulphur compound is entirely removed from the petroleum solution, the reaction then tails off and, finally, a slow spontaneous decomposition of the residual dilute acid hypochlorite continues to take place. A considerable evolution of heat occurs at and immediately after the point in the reaction marked (*); the oxidation at this stage is so rapid that it is impossible to isolate any intermediate compounds.

Although the reaction is considerably slowed up by the addition of even a little alkali, it is interesting to note that even 20% of sodium hydroxide does not completely inhibit the oxidation.

MERCAPTANS.

The apparent course of the reaction between sodium hypochlorite and a mercaptan depends greatly upon the alkalinity of the former. The first action, as stated above, leads simultaneously to the formation of the sulphonic acid, sulphuric acid, and the disulphide; the last, if the reagent is sufficiently

active, is destroyed as it is formed, and the acids, as their sodium salts, are the only products. But with a more stable solution of hypochlorite a much slower decomposition of the disulphide occurs, and this substance then appears as the chief product, accompanied by smaller quantities of the acids which have been formed, for the most part, by direct oxidation of the mercaptan. The first part of the reaction, in which the mercaptan itself takes part, does not appear to be greatly affected by the alkalinity of the reagent, whilst the factors which influence the destruction of the resulting disulphide are those which govern the normal interaction of this type of compound with sodium hypochlorite. The oxidation may be represented diagrammatically thus :



HYDROGEN SULPHIDE, ELEMENTARY SULPHUR, AND THIOPHEN.

As stated above, by the action of sodium hypochlorite on hydrogen sulphide, sulphur and traces of sulphuric acid are produced. Part of the sulphur becomes dissolved in the oil ; this emphasises the necessity for a preliminary soda-wash on any distillate which is likely to contain hydrogen sulphide and which is to be hypochlorited. Since sulphur is not attacked by hypochlorite solutions the sulphuric acid must be formed directly from the hydrogen sulphide.

It was found that thiophenes were not attacked by sodium hypochlorite, at least not under the conditions employed. There is, however, no evidence that these substances are present in Persian oil distillates.

Under certain conditions of insufficient alkalinity the action of hypochlorite solutions on distillates leads to the production of oil-soluble substances that react with alkalis. As these substances are not present as free acids they are not completely removed by ordinary soda-washing, although this may be readily accomplished by employing a means of agitation sufficiently thorough to bring about contact between the dissolved acidic bodies and the aqueous soda. With the even better contact afforded by the use of weak alcoholic soda hydrolysis is complete and rapid. That these substances are of somewhat high molecular weight is shown by the fact that they may be adsorbed on bauxite or concentrated into the heavy residue on redistillation.

Tests on sulphur compounds of various types showed that only one class—those containing an .SH group—could be converted into this type of substance on treatment with hypochlorite solutions. The lower mercaptans and hydrogen sulphide gave only traces of such bodies, but under regulated conditions large amounts were formed from the higher mercaptans. Analysis of the material produced from *iso*amyl mercaptan in light petroleum solution

indicated that hydrogen chloride constituted a molecular proportion of 0.5 to 0.85 of the total hydrolysis products, the remainder being *isopentane* sulphonic acid. Attempts to isolate definite compounds led to the separation and identification of *isopentane* sulphonyl chloride, but it was obvious that other compounds, containing more chlorine, were also present.

It is highly probable that these substances are derived from the pentachloride $R.SCl_5$, and consist of a range of bodies varying, by progressive hydrolysis, from this compound to the sulphonyl chloride $R.SO_2Cl$.

LITHARGE PROCESS.

The reagent sodium plumbite or "Doctor Solution" (Compare Wendt & Diggs, Journ. Inst. Petr. Techn. Abs. 1924 (Dec.) 406A.) is prepared by dissolving litharge in caustic soda. It consists of $Na_2 PbO_2$. The only organic sulphur compounds (present in petroleum distillates) which react with it are the "acidic" compounds, i.e. H_2S and mercaptans. Hydrogen sulphide at once precipitates black lead sulphide. Mercaptans form mercaptides thus :—

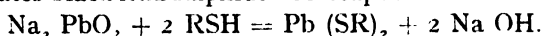
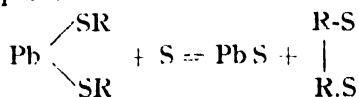


FIG. 24—Continuous Washing Plant. The spirit and the hypochlorite solution move in a counter current direction.

The mercaptides are yellow and insoluble in the aqueous layer. The lower members are insoluble in the oil, but the higher members are colloiddally soluble, and in order to make them "floculate" it is necessary to add free sulphur. This oxidises the mercaptides with the formation of lead sulphides (which is precipitated) and disulphides.



It can thus be seen that no desulphurisation occurs due to elimination of the mercaptides as mercaptides, for the disulphides formed are exactly equivalent to the mercaptides originally present. The disulphides being soluble pass back into the oil, which is now, however, "sweet" both to the "doctor" reagent and in odour. Thus the essential feature of the litharge or plumbite process is sweetening rather than desulphurisation (but see below).

At the same time, unless very careful control over the sulphur addition is maintained, a corrosive spirit is produced owing to the presence of excess of

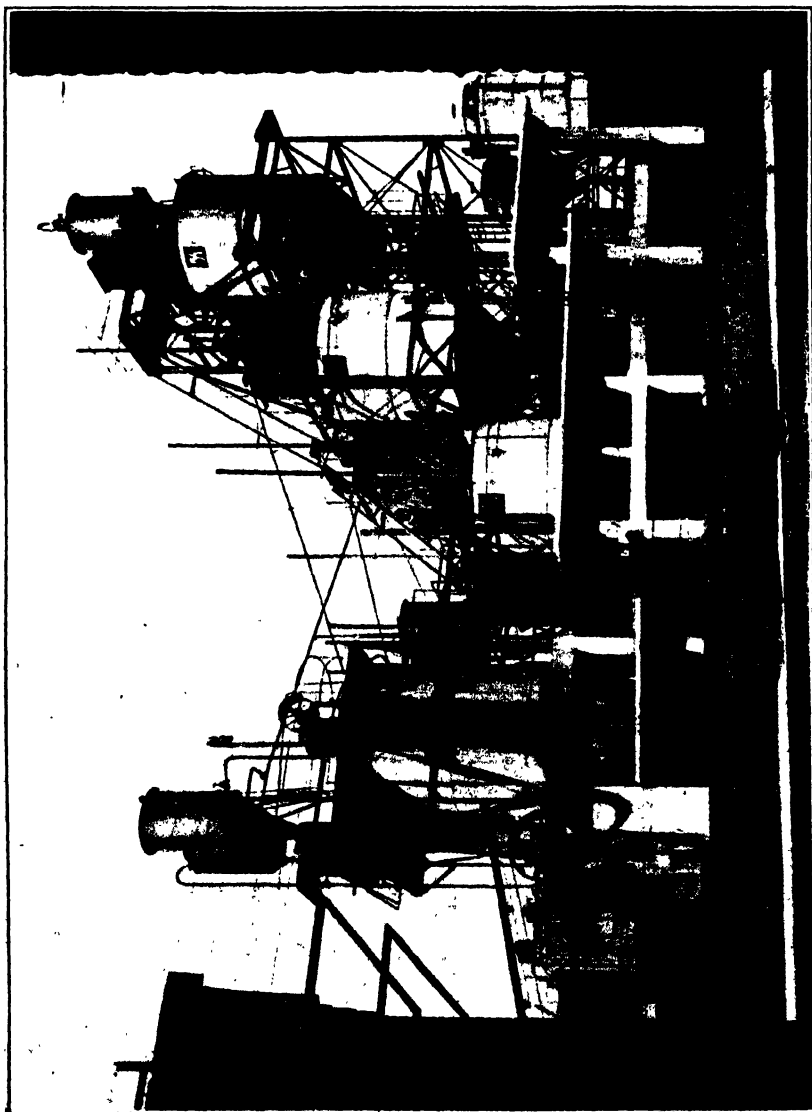


FIG. 25—Washing Plant.

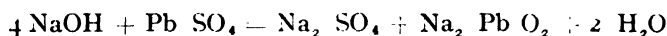
free sulphur. For convenience sake, the free sulphur is generally added in solution.

In the case of cracked spirit after the precipitate has been removed by settling, the distillate is acid treated. The acid treatment not only polymerises reactive hydrocarbons but causes dissolution of sulphur derivatives.

Desulphurisation does, however, occur in the plumbite process, for it has been shown that the precipitated lead sulphide is in a highly active adsorbent form and adsorbs sulphur compounds, thus bringing about some reduction of the sulphur content. A similar adsorbent action is exhibited by freshly precipitated mercuric sulphide and other metallic sulphides.

RECLAMATION.

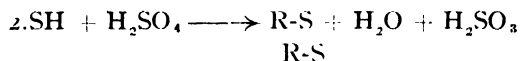
The lead is generally recovered by adding spent acid sludge whereby lead sulphate is produced. The lead sulphate after washing by settling is dissolved in caustic soda to give sodium plumbite.



A more recent process consists in oxidising the lead sulphide by air blowing at an elevated temperature.

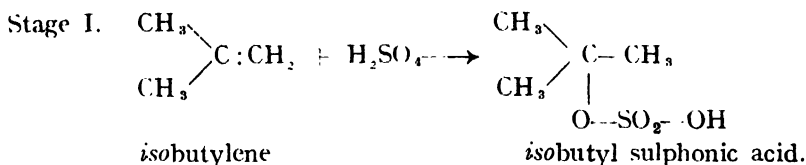
ACID REFINING.

The mechanism of refining petroleum distillates by means of strong sulphuric acid is well known*. Firstly, it is a good solvent for thio-derivatives, secondly, it is an oxidising agent and reacts with mercaptans as follows:—

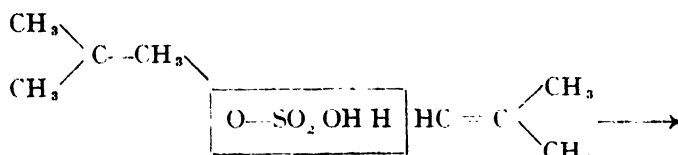


Thirdly, it brings about the flocculation of colloiddally dispersed colouring matter and finally reacts with olefines, diolefines and aromatic hydrocarbons, producing polymers, esters and sulphonic acids.

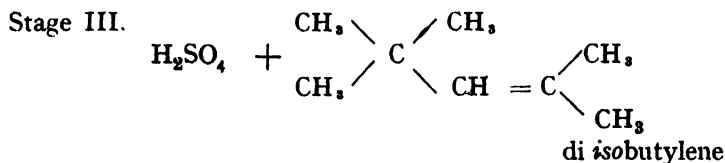
I. POLYMERISATION probably proceeds through the formation of esters:



Stage II.



* See Gurwitsch, "Scientific Principles of Petroleum Refining." Translated by H. Moore. Chapman & Hall. 1927.



The polymers thus produced are high boiling, and in the case of cracked spirit must be removed by redistillation.

Brooks and Humphrey, *J. Amer. Chem. Soc.*, 1918, **40**, 822. have discussed this point in great detail.

2. OXIDATION.

Sulphuric acid acts as an oxidising agent, and consequently after its use sulphur dioxide is invariably produced.

3. SOLUTION.

Recent work on Persian kerosene has shown that during refining by agitation with sulphuric acid, the reagent has almost a purely solvent action; the sulphur compounds are removed owing to their preferential solubility in the acid, and for the most part escape oxidation. The dilution of fresh acid tar from kerosene refining may therefore be expected to yield the sulphur compounds of the kerosene substantially unchanged.

This has been carried out on a large scale, 6,000 gallons of soda washed kerosene being treated with 1% by volume of acid for 30 minutes, and the acid tar, after settling, run into water. Some 30—35 gallons of a dark reddish brown, highly sulphurous oil separated, which had a peculiar, sweet odour resembling that of peppermint. This oil contained hydrocarbon (v.i.) as well as sulphur compounds. In order to concentrate the latter yet further, the treatment with acid was repeated, and an oil containing more than 5% of sulphur was obtained by diluting the acid layer. Distillation of this in a current of steam gave a pale yellow oil consisting essentially of the neutral sulphur compounds of the original naphtha.

From its high specific gravity and the smoky flame produced when burnt the portion of the original oil which remained undissolved during the second extraction with acid appeared to have a high content of aromatic hydrocarbons. Moreover, since the sulphur content was less than 0.5% and the odour pleasant, sulphur compounds (the nauseating odour of which is peculiarly penetrating) were evidently absent. The properties of this (apparently aromatic) oil were quite different from those of the original kerosene. On further investigation toluene, *m*- and *p*-xylenes, *p*-ethyltoluene, hemimellitene, mesitylene, cumene, ethylxylene, diethylbenzene, and naphthalene were identified. (Birch & Norris *J. Chem. Soc.*, 1925, **129**, 2545).

FLOCCULATION.

4. The flocculation of colloiddally dispersed colouring matter and the solution of molecularly dissolved colour are perhaps the most useful functions of this reagent, but, whereas, only a small amount of acid is required for these purposes, in effect, a large amount is used because of the existence of what may be termed side-reactions. Thus the effect of acid in removing entirely useful olefines and aromatic hydrocarbons must be borne in mind, so that in the conventional refining process aromatic sulphonic acids and alkylated acids pass away into the acid sludge.

Apart from the wasteful nature of acid refining, there are two other consequences that must be borne in mind. There is first of all the cost of disposing of the acid sludge, for which no simple, cheap and uniformly applicable method has yet been devised, and secondly, there is need for a subsequent alkali wash that may actually undo part of the work done by the acid, because droplets of acid tar suspended in the oil do actually undergo hydrolysis and the product is passed back again into the treated oil.

The combination, however, of acid and clay very directly minimises this last occurrence. In the case of a lubricating oil, for example, current practice is to agitate the oil with the necessary amount of strong sulphuric acid and then to remove suspended tar by further treatment with finely divided clay, that is, in effect, aluminium silicate characterised by the development of extremely great surface. This operation can be achieved either by direct agitation at a moderately high temperature or, better, by mixing the original clay with sulphuric acid, heating, extracting with water to remove soluble salts—thus “opening out” the clay—washing the clay free from acid and using the sludge or pulp to mix with the oil. The mixture is pumped through a pipe-still where intimate contact occurs between the oil and the clay, steam is disengaged and after separation of condensed water and clay, the oil is in a neutral condition. Some experiments have been made to utilise acid and clay for the refining of cracked distillates.

A further point may be mentioned in connection with acid treatment, and that is the application of acid at a low temperature whereby it is claimed that the side-reactions are largely eliminated. To some extent the acid behaves rather like the SO_2 in the Edeleanu Process (see R.A. Halloran, *Oil & Gas Journ.* 1927, Dec. 8., where 27°F . is suggested as a suitable temperature.)

NOTES ON BOOKS.

PITMAN'S TECHNICAL DICTIONARY OF ENGINEERING AND INDUSTRIAL SCIENCE, IN SEVEN LANGUAGES :—ENGLISH, FRENCH, SPANISH, ITALIAN, PORTUGUESE, RUSSIAN AND GERMAN. Part I and Part II each 2s. 6d. To be completed in about 36 Fortnightly Parts. London : Sir Isaac Pitman and Sons, Ltd.

This important or, indeed, unique undertaking of Messrs. Pitman, serves to remind us that a dictionary in the full and best sense of the term includes both phrases or verbal constructions, and ideas or concepts, as also single words ; indeed, the main function of a dictionary, as distinguished from a mere word-book or vocabulary, is the study and elucidation of the interrelation of words, ideas and phrases ; but with special emphasis on the cryptic or obscure phrases called idioms. The alphabetically-arranged dictionary as we understand it does not go very far back in time, and appears to be a consequence of the art of printing, many regarding a volume issued by Aldus of Venice, in 1502, as the first printed Lexicon or Dictionary in the ordinary sense of the term ; it being a kind of gazetteer of ancient cities and antiquities written by Stephanus Byzantius. Passing over many dictionaries, we may make a pause at Buxtorf's *Lexicon Hebraicum*, ninth edition, printed at Basle in 1689, as the short supplementary section, *Lexicon Breve Rabbinico-Philosophicum* gives us a distinct foreshadowing of the modern technical and scientific dictionary.

Mr. Ernest Slater, whose name appears on the cover of each of the two Parts now under notice, is mentioned as the compiler of the new Technical Dictionary ; that is to say, he is Editor in the usual sense of the term. Mr. Slater is favourably known as having been associated with engineering or technical work in various parts of the world, and as having acquired facility in various languages. He, however, does not rely on himself alone in the onerous task of producing an accurate, exhaustive, and up-to-date technical and scientific dictionary in seven languages ; but he has systematically referred foreign terms to persons of known technical standing who are natives of, or residents in, the countries concerned. Also, he has for some years been in close correspondence with many foreign helpers ; the result being that the numerous mistakes, blunders and absurdities which have hitherto characterised so many attempts to give foreign equivalents to English readers are reduced to an almost negligible minimum. Mr. Slater has striven nobly for perfection, but he does not profess to have realised that absolute perfection which cannot be expected in a work containing over a million words in foreign tongues. Mr. Slater's success is, however, a real triumph in the battle of patient labour against difficulties, and the success is definitely obvious in that which in Part I is termed "Section VI," but this so-called Section VI is the great work itself, the real Technical Polyglot which should mark a period in our workshop, commercial and industrial literature.

Of this great work (Section VI nominally, but actually the Technical Polyglot Dictionary proper) we have but a small fraction before us as we write ; only 71 pages : 7 at the end of Part I, and 64 which constitute Part II. We can, however, confidently hope to see the regularly-appearing fortnightly parts, about 36 in number, which are to complete the work, and to experience no falling off in quality. An owner of the complete work will have, ready for easy reference, an unbroken sequence of between two and three thousand 10 in. by 7½ in. pages ; these embodying about two million technical words, terms, ideas or phrases. At each opening of this sequence the reader will have in view the seven languages ranged in parallel

columns, so that a word or phrase is seen at one glance in all its seven linguistic aspects, but the alphabetical arrangement is only of service to those who read the English language. The usual device for making a work of this kind available all round is to recast for each language, which gives as many editions as there are languages; thus the three-language technical dictionary of Tolhausen, published by Tauchnitz about half a century ago, is triplicated for the convenience of those who know but one of the three languages: each language being first, and alphabetically arranged, in one of the three versions. A comparable course with the work under notice would be impracticable for several reasons. The cost of re-arranging the matter and printing the seven versions would be prohibitive, and a sevenfold price with sevenfold bulk would stand in the way. A possible method of making one version serve fully for all the nationalities involved is suggested by the edition of Buxtorf's Hebrew Lexicon mentioned above. Instead of doubling the size of the volume by adding a version with the Latin before the Hebrew, Buxtorf contrives a concise Latin index, or key vocabulary, showing the page or pages where elucidation of a Latin term is to be found, the space occupied by this index being trivial in relation to the bulk of the volume. We are inclined to think that if Messrs. Pitman apply Buxtorf's system to the work under notice, the six alphabetical key-vocabularies: French, Spanish, Italian, Portuguese, Russian and German, could be included in about 60 pages, a small addition to give something approximating to sevenfold utility.

The preface by Mr. Slater and the definitely prefatory pages (Part I, pp. III-IX) are of importance in many ways, especially as showing how the dictionary itself was obtained and as elucidating the psychological principles involved in making or obtaining good translations. On p. VIII there are several short lists of abbreviations as actually employed in the text of the Dictionary itself; thus, for example, R.A. signifies that the phrase or term involved is taken from the *Revista de Artilharia* and *horl.* after a word or expression indicates that it relates to clock or watch making. Glancing across to p. IX, we find a concise and lucid summary of recent simplifications of the Russian alphabet as adopted where Soviet administration prevails, but in the dictionary the old Russian usages are retained. Another good feature is the mention and explanation of certain dialectical variations from standard Portuguese which are incident to Brazil. In the dictionary itself both Lisbon usage and Brazil usage are given when the difference is important. This very useful Chapter concludes with a brief account of that "new" German spelling which has been standard long enough to make the old almost look pedantic. In the case of a work of the magnitude and importance of that which is before us, it is a convenience to the reader if numerical data, abbreviations, notices of literal changes and miscellaneous particulars, like those on pp. VIII and IX, are assembled on a special book-marker, a few copies being supplied by the publishers. Chemical readers will remember the printed book-markers issued by Messrs. Longmans with the second edition of the monumental Dictionary of Chemistry originated by Henry Watts.

The professed scope of the work under notice is to present, in seven languages, a formal and matured presentation of each technical or scientific idea which is included. We find, however, between Mr. Slater's prefatory pages and the seven-language dictionary itself, a sequence of 62 pages, evidently by a plurality of writers and containing much discursive information, but little that pertains strictly to this well-defined scope; unless, indeed, we extend the scope so as to make it include disjointed or unconnected remarks on the art of making such a dictionary. The first six pages of this interim matter form an article headed "The Art of Technical

Translation." The writer is original or novel in some of his concepts, and he appears to regard idiom as very closely interlocked with function, as will be seen by the tabulation on p. 3 under the heading "What is the function of the appliance to be named?" On page 4 we find this confident dogma as a kind of leading instance:—"If a machine chews or masticates rubber, there need not be the least hesitation in using words which correspond to the action of an animal's jaws." The writer is not happy in the selection of the masticator as an illustration of his linguistic views; Hancock's masticating machine having no hinged or alternating part; moreover, it neither perforates nor tears. On the contrary, it integrates, and this by a unique function which Hancock long kept secret. A reader who is interested can turn back in *The Journal* to the issue dated August 6, 1880, where Fig. 9 on p. 764 shows a section of a small model, and in the few lines of print immediately over the figure we read how Mr. Barker demonstrated to the Society the compacting of the spongy "washed-sheet" into a homogeneous mass. For the early history of Hancock's masticator from 1820 onwards, and the discarding of sharp teeth or spikes, see his work on India-rubber, published in 1857 by Messrs. Longmans.

Section II of the interim discursive matter includes the first of nine short studies in dictionary making, or, rather, nine actual specimen technical dictionaries, but the reader may be confused by the fact that the words "Technical Dictionary" are used as a running-title over all nine alphabetical sequences. The short article headed "Vacuum" in the first of the nine (p.21) has nothing to do with technics or foreign equivalents, but it commences with a dogma that "the phrase 'to create a vacuum' is wrong," the whole of the article consisting of contentions in support of this view. We now pass over seven of these dictionaries and arrive at the last, or shortest, where (p. 61) the writer tells us that "this list is merely supplementary, and is intended to fill a few important *lacunae*." We pass on to the Dictionary, or list, and find it the most trivial of the nine, spoken workshop slang being a leading feature. Thus the first term, "Ackey," appears to be merely a mispronunciation of acid, which, like assic, may be heard in many places.

Our remarks on the interim matter are not intended to suggest that it is valueless, as some parts are notably good, the short article on the word "Cut," (p.11) for instance; and the "Forms used in advertising," pp. 28, 34, 40, 46, and 58. These are, however, likely to be lost to the user owing to the five pages not being cross-referenced with each other, and the non-inclusion of "Advertising Terms" in the Seven Language Dictionary itself on p. 76. The triumphantly great feature of a dictionary is that it is one sequence and is its own index; but when a multiplicity of alphabetical lists or dictionaries are brought into certain aspects of association the advantage of an alphabetical arrangement may be lessened, extinguished, or made a source of actual confusion: thus a dictionary supplement should be, when practicable, a separate volume or detached part, like Richardson's Supplement, 1856, and the Supplementary Glossary of Davies, 1881. Such parts of the interim matter as are strictly relevant to the *Seven-Language Dictionary*, may be incorporated with the main work as it progresses, and possibly the six sectional linguistic key-vocabularies, already mentioned, may be compiled, and so paged as to fit where the discursive matter now is, so that any who desire the interchange may make it.

Nothing which we have said about the contents of pp. 1-62 affects our unservedly high opinion of the actual Dictionary proper, or dims our confident hope of a triumphant conclusion.

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*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C.(2.)*

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES

SCIENTIFIC FOUNDATIONS OF THE REFINING OF PETROLEUM.

By A. E. DUNSTAN, D.Sc. (London), F.I.C., F.C.S.

Vice-President and Editor of the Transactions of the Institution of Petroleum
Technologists; Chief Chemist, The Anglo-Persian Oil Co., Ltd.

IV.

THE REFINING OF PETROLEUM DISTILLATES.

(Continued).

(Delivered January, 1928.)

EDELEANU PROCESS.

Of outstanding importance as a highly scientific and yet practical refining method is the process originally devised by Edeleanu for the refining of Roumanian kerosene. As is well known this material contains a high concentration of unsaturated material that causes the oil to burn with a smoky flame. Edeleanu discovered that these unsaturated bodies were soluble in cold liquid SO_2 whereas the accompanying saturated hydrocarbons were sparingly soluble under the same conditions. Thus, if a mixture of benzole and hexane is agitated with liquid sulphur dioxide at below zero, a separation into two layers takes place after standing, the bottom layer consisting of in the main, a benzole solution in SO_2 and an upper layer of a little SO_2 dissolved in hexane. This is not entirely a rigid separation, because some hexane will dissolve in the SO_2 -benzole solution and some benzole will dissolve in the SO_2 -hexane solution. Furthermore, it is probable that there may be obscure chemical reactions as well.

In practice the plant consists of a mixing vessel in which the liquid SO_2 and the oil are admixed, every precaution being taken to ensure absolute dryness. After separation, the heavy extract layer is pumped through heat exchanges that chill down the incoming material, thence to evaporators where the SO_2 is removed by a combination of high temperature and reduced pressure. A similar happening occurs with the refined upper layer. The stream of SO_2

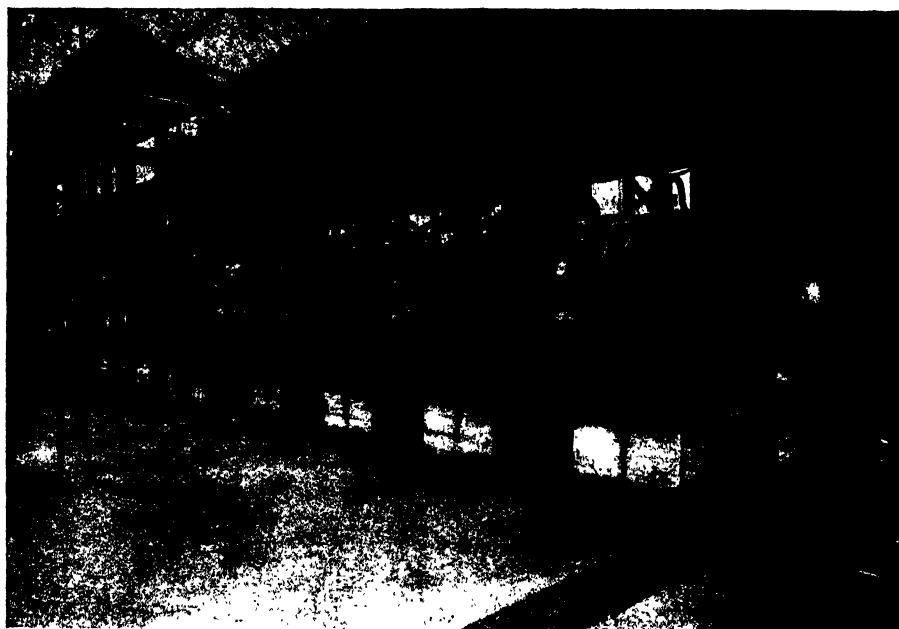


Fig. 26—Evaporation for removing SO_2 from Edeleanu Extract.

from both sets of evaporators passes into compressors and coolers and is again ready for service. Under ordinary conditions, there is not the slightest risk of corrosion trouble, provided moisture is excluded. The overall loss of SO_2 is of the order of a few tenths per cent. With an average kerosene the extract may vary between 10% and 15% by volume. The effect of SO_2 on sulphur content is, as would be anticipated, profound.

This is not surprising when it is realised that the sulphur atoms both in SO_2 and the thio-derivatives possess residual affinity. This being the case it is more than likely that chemical action comes into play. By no means is the extract to be regarded merely as a waste product. It contains part of whatever aromatic content the kerosene may have possessed, and consequently, it may be topped as a source of light aromatic hydrocarbon and the residue is a cracking stock of attractive potentialities. The refined oil is characterised by excellent burning test and low sulphur content.

Quite recently this process has been applied to the refining of lubricating oils where in some cases its need is particularly felt. It is well known, for

example, that the losses in refining crude lubricating oils are particularly heavy with a corresponding heavy consumption of acid and clay. In such cases a preliminary treatment with liquid SO_2 removes those bodies that are peculiarly attacked by acid, and the subsequent refining to the necessary standard of colour, odour, emulsibility and reversion is much easier. Here again the extract has some value; at the worst it is a fuel oil but it may conveniently be transformed into low grade lubricants or greases.

TABLE XIX.
EDELLEANU SO_2 TREATMENT.
BATCH METHOD. DISCONTINUOUS.

Oil Used.	% Treatment.	% Sulphur.		
		Original.	Refined Oil.	Extract.
Kerosine	One 100%	0.28—.30	0.11—.13	1.01—1.07
Blue Oil	One 100%	1.56	1.10	3.0
" "	One 50%	1.56	1.20	
" "	Two 50%	1.56	.90	
	Three 50%	1.56	.73	3.9
Master Lubricant	One 100%	1.8	1.4	4.0
H.O. & P.	One 50%	1.44	1.1	
	Two 50%	1.44	0.82	4.06
	Three 50%	1.44	0.63	
	Two 100%	1.44	0.74	

BAUXITE.

Among the many substances that possess adsorptive properties to a high degree are bone charcoal, specially prepared vegetable charcoals, Fuller's earth, floridin, certain clays of Californian and Japanese origin, silica and alumina. Some of the most effective of these belong to the category of inorganic gels which have been formed by the de-hydration of a hydrogel such as silicic acid or aluminium or ferric hydroxides.

A cheap and convenient gel is the mineral bauxite, which is composed principally of hydrated aluminium and ferric oxides associated with varying amounts of silica, lime, titania, and magnesia. The mineral in its natural state has no adsorptive qualities, but by roasting to an appropriate temperature most of the water of combination is expelled, whereby the peculiar porous structure is developed upon which the refining efficiency depends. The chemical composition of a bauxite has no bearing on its effectiveness as a refining agent: bauxites of very dissimilar composition will give identical results on the refinery, whilst successive samples with identical analyses may be entirely different in behaviour (3rd Report of the British Association Committee on Colloids, p. 91 *et seq.*)

As a refining agent for petroleum, bauxite has marked advantages over many other substances which also possess adsorptive properties. The size of the

pores and nature of the surface happen to be just appropriate for the purpose in view, namely, the adsorption of the organic sulphur compounds and colouring matter which it is desirable to remove from petroleum distillates. It can be used in granular form (which obviates the need for filter presses and accelerates the filtration process), and can be recovered indefinitely (apart from loss due to disintegration). Though it is now known that bauxite when suitably prepared has the power of selectively adsorbing both colouring matter and sulphur compounds, the latter property is of comparatively recent discovery. The use of this material for decolorising kerosene and paraffin wax, however, was adopted by the Burmah Oil Company many years ago.

The procedure used at the Burmah refinery was as follows:—The bauxite was placed in cylindrical filters measuring approximately 8 ft. by 2 ft. 6 in., and holding about one ton, and the kerosene or wax was percolated through until the colour of the outcoming oil was no longer up to the required standard. The spent bauxite was then treated with benzine in a Merz extractor (after the manner of the Soxhlet apparatus) until no further removal of the adsorbed coloured compounds and adherent wax could be brought about.

The extracted bauxite, after removal of adherent benzine, was passed through a vertical furnace into which it was dropped from a hopper at the top, and fell from one sloping firebrick plate to another until it passed out at the bottom. During the whole period of its passage it came into direct contact with the hot gases (mixed with excess of air) from an oil burner, which oxidised any carbonaceous matter of hydrocarbons remaining after the extraction. It was then cooled as quickly as possible.

When it is necessary to purify kerosene containing both coloured matter and odoriferous sulphur compounds, it was found that it was not necessary to remove the sulphur compounds by chemical treatment before using the bauxite for decolorising (though this procedure may still be preferable in certain circumstances on considerations of cost), and that an appropriate bauxite treatment would effect the double purpose.

In a series of experiments bauxite was first heated to dull red heat in an oven and used at a temperature of 200°. This treatment reduced the sulphur in a given kerosene from 0.134% to less than 0.02%. It was found, moreover, that under the same conditions, but allowing the bauxite to cool in the open air before use, the resulting sulphur content was 0.11%. In the light of recent research these results were due, not to the temperature at which the bauxite was used, but to the absence of absorbed moisture, etc., from the pores. The proportion of bauxite to kerosene was varied in a series of experiments from 2 to 9 lb. per gallon with the results shown in Table 20.

The following conclusions were arrived at from these experiments:—

(1) Bauxite is a colloidal adsorbent of the first order for organic sulphur derivatives.

(2) Freshness of preparation gives best results—*i.e.*, ignition immediately before use.

(3) Bauxite, *per se*, is a complete and sufficient refining agent for kerosene.

(4) Other light, sulphur-containing distillates are also capable of purification by this process.

TABLE XX.

Material.	Treatment.	Sulphur. %
Kerosene	None.	0.134
"	9 lb. bauxite hot from oven, temperature approx. 200°*	0.017
"	4 lb. bauxite hot from oven (200°).	0.017
"	9 lb. bauxite not freshly ignited.	0.110
"	5 lb./gal. hot from oven.	0.018
"	2 lb./gal. cooled after ignition.	0.098
"	3 lb./gal. hot from oven.	0.03
"	2 lb./gal. hot from oven.	0.06
White Spirit	Untreated	0.078
"	2 lb./gal. hot from oven.	0.022
"	Spirit ex steamed bauxite.	0.18
Benzine.	2 lb./gal. hot from oven.	0.014
"	Untreated.	0.078
"	Spirit steamed out of the spent bauxite.	0.44

* Minimum time from oven to treatment.

It was found that the adsorbed sulphur compounds could be to a large extent removed from the exhausted bauxite by means of superheated steam, and, to a lesser extent, by hot water.

In spite of the fact that bauxite has been used for many years in the refining of petroleum, the mechanism of the reactions which take place has only been explained recently. It is now practically certain that the phenomenon is one of surface and pore adsorption, and the action of bauxite upon sulphurous oils appears to be strictly analogous with known cases of true adsorption, although it is more than likely that chemical action follows on adsorption (see Gurwitsch-Moore, *Scientific Principles of Petroleum Refining*. Chapman and Hall).

(1) Material such as roasted bauxite containing large numbers of microscopic pores is well known to possess an enormous surface area and consequent surface energy.

(2) When oil is allowed to come into contact with freshly-ignited bauxite a considerable rise in temperature is observed, due to the surface energy being converted into heat energy.

(3) Bauxite obeys Freundlich's rule, which may be summarised as follows : $(x/m)^n$ is proportional to c , where (in this case) x = % of total sulphur adsorbed by bauxite, m = wt. of bauxite per 100 parts of kerosene, c = % of sulphur in kerosene before filtration, n = a constant.

EXPERIMENTAL VERIFICATION OF THE FREUNDLICH LAW AS APPLIED TO THE ADSORPTION OF SULPHUR AND COLOUR COMPOUNDS FROM KEROSENE BY BAUXITE.

As a starting point, the residue from soda-washed naphtha was used (sulphur, 0.3% ; colour in $\frac{1}{2}$ in. Lovibond cell, Y 8.4, R 2.5). Samples (150 c.c.) of a wide range of sulphur and colour concentration were prepared by treatment with quantities of bauxite varying between $\frac{1}{4}$ to 10 lb. per gallon. As the colours to be measured extended far beyond the range of the usual tintometers, a column of the liquid, of which the colour had to be measured, was matched against an equal column of the original crude kerosene diluted with benzine, in the Saybolt colorimeter. The colour concentrations so measured were expressed as percentages of crude kerosene (thus the colour of the original kerosene = 100).

4. *Colour*.—Six of the above samples with colours ranging between 100% and 1.7% were treated with $\frac{1}{2}$ lb. of bauxite per gallon. The bauxite (20-90 mesh) was roasted 1 hour at 500°-540°, and cooled in a desiccator. 70 c.c. of each sample of kerosene were shaken for ten minutes with 3.5 g. of bauxite at 20°-21° in the mechanical shaker (5% by weight, or $\frac{1}{2}$ lb. per gal.) :—

TABLE XXI.

Initial Colour	Final Colour.	% Colour removed.	x/m.
100	52	48	9.6
58	32	45	5.2
42	21	50	4.2
14.2	5.5	61	1.74
4.6	2.2	52	0.45
3.5	1.7	52	0.34
1.7	0.8	53	0.17

The values of x/m (amount of colour adsorbed per gram of bauxite), plotted against the initial colour concentrations, give approximately a straight line. Hence, for coloured compounds x/m is proportional to the initial concentration of the colour, and the Freundlich law is followed approximately. The constant n equals unity.

B. *Sulphur*.—Six of the above samples having sulphur concentrations ranging between 0.23% and 0.017 % and colours from 3.5 to 0 were treated with 2 lb. of bauxite per gallon. The bauxite was prepared in the same manner as before. 70 c.c. of each sample were shaken as before, with 14 gr. of bauxite, i.e., 2 lb. per gallon. (See Table 22).

In this case x/m = grams of sulphur adsorbed per gram of bauxite. These values, when plotted against the initial sulphur concentration, give a graph which more or less approximates to a straight line. If the logarithms of the quantities are plotted a curve is obtained which approximates more closely

to a straight line. Hence it is concluded that for sulphur compounds the adsorption only approximately follows the Freundlich law. The mean gradient of the log curve indicates that the value of n is of the order of 1.3, i.e., $(x/m)^{1.3} = k.c.$

The deviation is, no doubt, due to the disturbing influence of coloured compounds which are preferentially adsorbed.

With regard to the question as to whether the Freundlich law holds good for the simultaneous adsorption of both colour and sulphur compounds, the

TABLE XXII.

Initial % S.	Initial Colour.	Final % S.	% S removed.	$\frac{x}{m}$	$\log \frac{x}{m}$
0.189	1.9	0.232	19.7	0.222	1.3463
0.230	3.5	0.20	13	0.117	1.0682
0.207	1.4	0.168	18.9	0.152	1.1818
0.126	0.6	0.103	18.3	0.090	2.9542
0.096	0.2	0.074	23	0.086	2.9345
0.027	—	0.017	37	0.039	2.5911

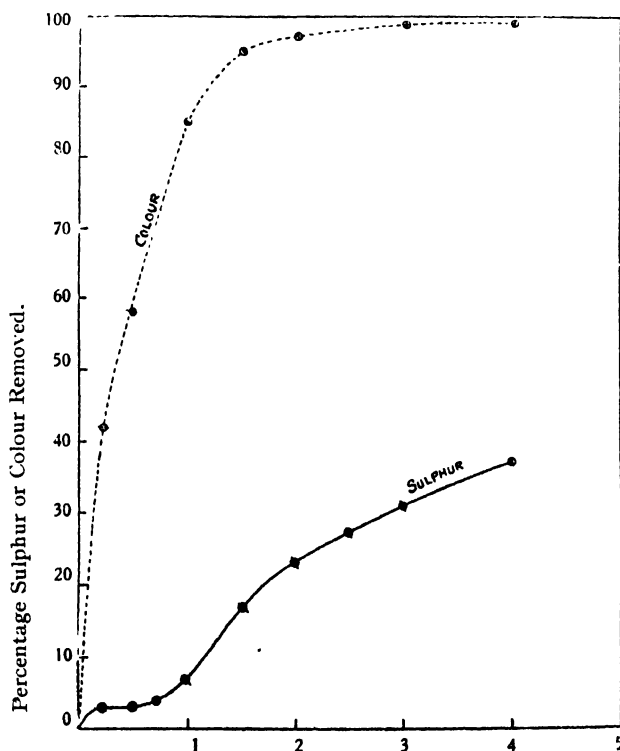


Fig. 27—Pounds of Bauxite per Gallon.

results are best understood by reference to the accompanying figure. This was obtained by treating kerosene of high colour and sulphur content with varying amounts of bauxite. (Fig. 27).

The curve clearly shows that the coloured compounds are adsorbed much more rapidly than, and in preference to, the sulphur compounds. Thus, until 85% of the colour has been removed only a small fraction of the sulphur is taken up, but once the colour is adsorbed then the removal of sulphur follows the usual course.

The point representing colour 3.5 (Table 22) lies considerably below the line x/m sulphur. The comparatively high colour concentration has lowered the adsorption of sulphur. This bears out the theory of preferential adsorption of colour.

BAUXITE AS A POLYMERISING AGENT.

Like all substances possessing a structure consisting of ultramicroscopic capillary tubes, bauxite has the power to bring about chemical changes in compounds with which it comes in contact. This is mostly in evidence among unsaturated hydro-carbon compounds (*e.g.*, pinene and amylene are converted into dipolymerides), and is also seen in the case of the sulphur compounds present in petroleum oils. Decomposition and polymerisation both take place, the intensity of the reactions being favoured by increase of temperature.

If cracked spirit, which contains a large proportion of unsaturated hydro-carbons, is filtered cold through bauxite, the filtrate will be far deeper in colour than the original, and if colourless beforehand, the spirit will issue from the filter with a deep yellow colour. By maintaining the bauxite at about 100° an orange-brown filtrate is obtained, but if the temperature is raised above the final boiling point of the spirit, say 200°, the issuing vapour on condensing will be perfectly colourless and substantially free from sulphur compounds. The explanation of these results is as follows:—Polymerisation of unsaturated compounds takes place in contact with the bauxite to strongly-coloured gums of high molecular weight and boiling point. In the case of filtration, both in the cold and at 100°, the incoming liquid dissolves these gums and washes them out of the bauxite, but in the vapour phase method the gums remain in the filtering material because their boiling point is above the surrounding temperature. A similar reaction takes place in the case of the sulphur compounds, the majority of which are very reactive and readily undergo polymerisation.

Two methods of refining petrol or cracked spirit are therefore available: (a) by passing the liquid into bauxite maintained at a temperature of about 200°, when it instantly vaporises and passes through the filtering medium in the state of vapour, and (b) by passing the liquid through bauxite maintained at 100° and re-distilling the filtrate in the ordinary way. In process (a) the gumming polymers remain behind in the bauxite and gradually contaminate it,

but a finished product is obtained in one operation. In process (b) the polymers are washed out of the bauxite, and thus the active life of the latter is maintained for a longer period. In the subsequent distillation the polymers, being of high boiling point, remain behind in the still, and a colourless distillate is obtained which is free from those compounds which form gum in cracked spirit on standing. The sulphur compounds in petrol are removed in the same way as the gum-forming compounds in cracked spirit. Sulphur compounds in kerosene can also be removed by an adaptation of process (b), wherein kerosene is filtered through bauxite at a temperature of 100° - 130° and then cooled and filtered through bauxite at the ordinary temperature. By polymerising the sulphur compounds in the hot filter they are rendered more easily removable by the cold filter than would have been the case if the hot filter were replaced by a cold one. A crude kerosene with a sulphur content of 0.31% was filtered through bauxite maintained at 120° at the rate of 1 lb. per gallon, and the filtrate then re-filtered through cold bauxite at the same rate. After the passage through hot bauxite the sulphur content was 0.26%, and after the subsequent cold filtration it fell to 0.16%. Ordinary filtration through 2 lb. of cold bauxite gave a filtrate with a sulphur content of 0.21%.

The present method of using bauxite may be divided into the following stages:—

(1) *Filtration*.—A predetermined volume of oil is filtered through a definite weight of bauxite.

(2) *Steaming out*.—The filter is steamed out until no further kerosene can be removed economically.

(3) *Make-up*.—Fresh bauxite is ground to size, and the required quantity added to make up for losses in working.

(4) *Roasting*.—The fresh make-up bauxite and the spent material are roasted in excess of air to remove moisture, the last traces of kerosene, and firmly retained organic matter and carbon, thus freeing the pores for a new run.

In order to understand the conditions required for successful filtration, it is necessary to consider the coloured compounds, and sulphur compounds contained in the oil, which may be divided roughly into two groups:—

(1) Those in true solution (sulphur derivatives);

(2) Those in colloidal suspension (colouring matter).

Solid matter in coarse suspension can be removed by purely mechanical filtration through non-adsorbent material such as sand, but matter in solution or colloidal suspension can only be taken out by true adsorption into the pores of some active material of the nature of bauxite. The top layers of the bauxite are therefore engaged in removing the suspended coloured compounds, which cover over the pores and prevent the matter in solution from being adsorbed until it reaches a lower stratum, at which point all the suspended material has been left behind. As soon as these coloured compounds have been removed

the bauxite is ready to deal with the sulphur compounds, which are hardly touched at all until the major part of the colour has already gone.

Taking, then, the successive layers of bauxite in a filter, the top is occupied in mechanically removing suspended matter, the next layers eliminate the sulphur compounds. In this way the three active zones move downwards until the coloured compounds are being extracted at the very bottom of the filter. But as no sulphur is taken out until almost all colour has gone, it will be seen that at this stage no sulphur is being eliminated at all. In other words, the bauxite is exhausted for desulphurising purposes; it is still capable, however, of removing colour.

For this reason "series-filtration" gives the most efficient and economical results. The principle underlying series filtration is that of putting the various layers of a large filter into a number of smaller filters, so that each layer is, capable of rejection as soon as it is exhausted, while no layer is rejected until completely exhausted both for decolourising and desulphurising.

In working the series-filtration much light was thrown on the elimination of colour and sulphur compounds, for it was found that it was only when the filtrate came in contact with fresh bauxite in the last filter that any substantial desulphurisation took place. Colour was progressively removed in passing through the series of filters, but sulphur compounds were only removed in the last filter, as is shown in the following table :---

TABLE XXIII.

Filter.	Colour of filtrate (Saybolt)	% S in filtrate.	% of total S removed by filter.
1	16°	0.286	0
2	17°	0.286	0
3	18°	0.286	0
4	19°	0.252	12
5	22°	0.129	52

After the bauxite is exhausted it is allowed to drain for about one hour, and is then steamed out. Shortly after steam begins to issue from the bottom of the filter the extraction is stopped, and bauxite thus treated with superheated steam (150°) comes out dry to the touch, though still containing 7-12% of moisture and kerosene. Further steaming removed but little kerosene in proportion to the amount of steam used.

The bauxite is next roasted to remove moisture and burn out adsorbed impurities that are not removed by steam. This necessitates a temperature of about 550° in the presence of ample air.

FURNACING.

Any furnace to be successful must satisfy the following desiderata :—(1) Too much grinding and crushing should not take place. (2) Whilst maintaining the temperature required, ample air must be present so that sufficient oxidation may take place. (3) The roasting temperature of 550° must be maintained for a sufficiently long time.

After draining a filter, 90% of the remaining adherent kerosene can be removed by steam, the major portion being expelled before steam issues from the bottom of the filter, and by using steam at 150° - 180° the bauxite is left dry to the touch and easy to handle. Another advantage in the steaming process lies in the fact that expulsion of the evil-smelling sulphur compounds does not commence until most of the kerosene is already displaced, whereby it is possible to recover a large portion of the retained kerosene in a fit state for re-filtering.



FIG. 28.—Rotary Furnace for Roasting Bauxite.

Various theories have been put forward to account for the supposed " poisoning " of bauxite after prolonged use, such as the formation of sulphates or chlorides of aluminium or iron by the sulphur and chlorine compounds in the oil. Analyses, however, have proved that no accumulation of either sulphate or chloride takes place provided efficient roasting has been employed. The same sample of bauxite has been used and recovered over and over again with very little loss in efficiency and practically no change in chemical composition. Formation of dust, due to repeated roasting and cooling, brings about a slow, progressive, slight decrease in efficiency, but an occasional sieving will prevent this and maintain a regular standard of activity.

The following tables give examples of regeneration experiments carried not by steaming at 120° and roasting at 600° .

TABLE XXIV.

	Colour of Filtrate. (Saybolt).	Sulphur content of Filtrate.
	°	%
Fresh bauxite	18	0.22
1st regeneration	17	0.20
2nd "	16	0.23
3rd "	13	0.19
4th "	13	—
5th "	15	—
6th "	17	0.23
Fresh bauxite	20	0.18
1st regeneration	18.5	0.19
2nd "	18	0.19
3rd "	17	0.19
4th "	17.5	0.19
5th "	18.5	—

TABLE XXV.

Temp. of Roasting.	% Moisture remaining.	Colour of Filtrate (Saybolt).	% S removed.
°			
None	—	—	—
200	26	3	—
300	9.7	20.5	24
400	4	23.5	48.5
500	1	22.5	58.6
600	0.68	21.5	65.6
700	0.34	21.5	61.2
800	0.22	20.5	—
900	0.0	20	40.3

The highest temperature attainable in the furnace used was 900°, and this was taken as giving completely anhydrous bauxite. Other workers, however, employing temperatures of 1,500°, as in the ceramic industry, have observed that bauxite shrinks to about half its original volume and in this state is quite valueless as a filtering agent. This is due to collapse of the capillary pores owing to partial fusion of the bauxite, and it can be seen in the above table that this phenomenon commences between 700° and 800°. For all-round efficiency fresh bauxite should be roasted at about 400°—600°.

For ease of manipulation and freedom from breakdowns horizontal rotary furnaces have proved their superiority over the multiple-hearth vertical type, but it cannot be said that even the former are by any means perfect. Recent investigations into the action of sulphur dioxide and carbon dioxide gases on the efficiency of bauxite as a filtering medium indicate that exposure to flue gas at a high temperature, such as occurs in the rotary furnaces, tends to decrease the property of removing certain sulphur compounds from oil. External

heating of the furnaces is not yet practical on the large scale, but the fact that better results are always obtainable in a laboratory furnace (which is thus heated) point to contamination by flue gases being of some importance in practice.

It has also been shown that oil or gas used in the burners must be as free from sulphur as possible in order to keep the quantity of sulphur dioxide in the flue gases down to the lowest possible limits.

INFLUENCE OF TEMPERATURE ON FILTRATION.

It has been found that in laboratory experiments sulphur compounds are more readily removed from the oil when filtration is carried out at a low temperature, but although this is very definite on the small scale it has not been found practicable to make use of the phenomenon in works practice. In laboratory experiments it was shown that at temperatures below the freezing point of water the amount of sulphur compounds removed was nearly double that at above the boiling point ($-10^{\circ}\text{C}.$ and $150^{\circ}\text{C}.$) whilst at intermediate temperatures ($50^{\circ}\text{C}.$ to $100^{\circ}\text{C}.$) a steady medium removal took place. Colour and odour removal followed the same lines, but was even more marked than in the case of sulphur compounds.

COOLING OF BAUXITE.

The influence of temperature on the results of filtration described above has a practical bearing on the necessity of cooling the bauxite to the lowest possible point on coming from the roasting furnaces before allowing oil to flow on to it in the filters. A difficulty arises from the fact that bauxite readily absorbs moisture from air on cooling, and in doing so loses much of its desulphurising and decolourising properties. To obviate this it has been the practice to start the filtration when the bauxite is still at a relatively high temperature in order to shorten the time during which exposure to air occurred, but by so doing a loss of efficiency (as explained above) had to be faced owing to the temperature at which the initial part of the filtration took place. The most effective means of overcoming this difficulty consists in transporting the red hot bauxite direct from the furnace to the filters by blowing it with air along a closed pipe. The velocity of the air is so regulated that the particles of bauxite actually float in the air stream and are thus not disintegrated by rubbing on the walls of the pipe. The same air may be used over and over again in a continuous cycle and therefore always remains dry, whilst the loss of heat during the passage through the pipe is so rapid that the bauxite arrives at the filter almost cold.

ACTION OF BAUXITE ON SULPHUR COMPOUNDS.

Although bauxite has been employed for a considerable time in eliminating from oil those organic compounds of sulphur which give it an objectionable

smell and are deleterious in other ways, the possible mechanism of the reactions taking place has not been closely studied until recently.

The necessity for closer investigation was forcibly brought to notice by repeated failure of filters to remove some of the mercaptan contents whilst still delivering oil with a sufficiently low concentration of sulphur for commercial purposes, provided the oil had been sweet.

An investigation was started on the action of bauxite on each of the separate classes of sulphur compounds known to exist in Persian oil, work only made possible by previous work on eliminating and identifying all the sulphur derivatives contained in this crude.

The results of this investigation, so far as it has gone at present, have proved extremely informative, and have made it necessary to readjust most of the previously held ideas on the course of the reaction. It is now evident that only certain sulphur compounds are actually physically absorbed by the bauxite, whilst others, including the evil-smelling mercaptans, are oxidised by contact with the air held in the bauxite and converted into compounds capable of being retained by the filtering medium. The presence of carbon dioxide in the place of air in the pores of the bauxite prevents the oxidation of the mercaptans, and these then pass through the filter without being absorbed. Similarly, sulphur dioxide uses up the oxygen in the bauxite and renders it incapable of transforming the mercaptans into absorbable bodies. These experiments have, therefore, clearly proved the necessity for using oil or gas with a very low sulphur content in the roasting furnaces, and also explain why the laboratory furnaces, which are externally heated and have only pure air passing over the bauxite, give better results than the works furnaces in which the hot gases from the oil or gas burners come in direct contact with the bauxite.

NOTES ON BOOKS.

NEW VENTURES IN BROADCASTING. London: The British Broadcasting Corporation, Savoy Hill, W.C.2. 1s.

Monsieur Thiers, who was a distinguished man, said : *Je ne crois pas aux chemins de fer*. Since his day, distinguished and obscure men alike have been nervous of expressing disbelief in the latest invention of universal importance. Disapprobation may be expressed for inventions in general, for this mechanised age, lock, stock and barrel. Monsieur Thiers would certainly have to "believe" in railways if he were resuscitated to-day, but that does not mean that he would have to approve of them--or of turbine steamers, aeroplanes, the cinema and the wireless.

The power of the wireless is great. One South American Republic which is stably governed is said to owe its comparative tranquillity to the fact that its President has a well-organised radio system in addition to a handful of loyal garrisons. *The Daily Mail* is powerful because it has a million and a half of readers ; but the

B.B.C. has between ten and twelve millions of listeners-in. Father Ronald Knox, to amuse himself, once announced, from 2LO I believe, that a revolution had broken out in London, thus in a moment causing a quite unprecedented amount of emotion all over the country. The power of the wireless is great. But power for what? Everything?

A commission of men and women has set forth fifteen recommendations upon the assumption that the wireless has power to educate adults. The commission advocates close co-operation between existing educational bodies, an increase of serious programmes, and a development of the system of supplementing wireless lectures with illustrative printed matter. It is explained in "New Ventures in Broadcasting" that a lecturer who, dispensing with "a dull introductory paragraph" plunges at once into "some arresting point," is able to stimulate his hearers to the pitch of wishing to take up a new subject. With the help of further wireless lectures and the auxiliary literature they will then proceed to master the new subject and become more educated than before.

Now we may safely say that nothing short of an astral disaster is going to prevent the carrying out of experiments on the lines indicated above, such experiments as are already being tried in Germany, Mexico and elsewhere. We may reasonably expect that the level of public instruction will be raised by such means, and that the cause of public education will be forwarded in some degree. But presumably the ladies and gentlemen on the commission are not under the delusion that even the most genial bureaucracy, aided by experts and modern science, can do very much very quickly to spread culture. As to technical education by wireless: it is hard enough to teach a class of twenty at the other end of a room, how much harder to teach a class of twenty thousand at the other end of a sound wave?

A distinguished lecturer told me some days ago that after he had broadcasted he received friendly letters of thanks from many countries; he was persuaded that the wireless is an agent making for international amity and understanding. I hope he may be right, and that he may not live to be sniped in a front line trench by one of his foreign admirers. It is natural to be sceptical about such things after the events of 1914-1918.

Knowledge is not education. Ingenuity is not education. Alas! "dull introductory paragraphs" are a more important element in education than "arresting points." The dons in our great colleges do not begin their lecturing by serving round condensed summaries of the most up-to-date books on their subject. On the contrary, they take pains to refer to none but books that are out-of-date.

Can the wireless contribute to the formation of better taste by the nation or the world at large? That, I feel, is the important question. It is agreed by the whole commission that "the provision of recreation and entertainment has been, and still is, one of the main functions of the broadcasting service. . . ." Also, that to some recreation "may mean the best music of yesterday and to-day. . . ." The English are inclined to like music, though their facilities for hearing it are less than those of the French, Germans and Italians; one hopes that the wireless, sensibly directed, may be of some use in supplying the demand for good concerts.

Professor Feuchtwanger believes that "the future" of the wireless lies in "talks." Certainly talks and readings of poetry and debates should be broadcast. Perhaps the radio can do more indirectly than directly for education. Meanwhile money spent on experiments with this extraordinary medium is not to be grudged; let there be more lectures and fewer aeroplanes.

An article by Mr. Douglas Goldring in the *Observer* of the 22nd July has a bearing on the question of mass education. He is writing about Sweden, a country which has "for generations made a fetish of education." He says that "the most striking result of Sweden's efforts in public education has been an enormous 'levelling-up' of the masses to a lower middle class standard. This . . . has produced a state of things which can hardly satisfy anyone but the statisticians." In short, professional men, learned men, truly educated men, find it more and more difficult to earn a living, while a standardised class of prosperous artisans is becoming ever more powerful.

In England the position of the professional class is not particularly secure; the levelling-up of the masses to a mediocre standard is going on apace here also. Is the wireless destined to hasten this process?

P.B.

OLD ENGLISH BRONZE WOOL WEIGHTS. By H. C. Dent. Privately printed.

The study of weights and measures is an absorbing one, especially, perhaps, in its origins. None the less, Captain Dent's account of the English wool-weights is most interesting; and it forms a large part—though so slim a volume—of our literature on the subject.

The importance throughout the middle ages and into modern times of the English wool trade explains the existence of specific wool weights. The Restoration Government, to stimulate the home demand for wool, actually enacted that the dead should be buried in shrouds of this commodity. Captain Dent quotes from the register of Worstead itself:

1728: Sarah, daughter of Charles Themylthorpe and Sarah his wife, was Buried November 25 and in linen, and penalty paid according to Act of Parliament.

The standard wool-weights were shield shaped, measuring six inches by four-and-a-half, one and three-quarter inches thick, while they mostly weighed seven pounds; sometimes fourteen or twenty-eight. The weights were perforated for the reception of the leather strap by means of which they were slung across the Tronator's horse.

Wool-weights were frequently re-issued, though the national system of weights and measures was—during comparatively recent history—reformed only three times: by Henry VII, Elizabeth and George IV. (Henry made Members of Parliament responsible for the safe delivery of the standards in their Boroughs.)

The weights were cast and stamped by the Founders' Company, which had charge of such matters since the thirteenth century and kept it till the nineteenth century. Captain Dent has much to say about the Company's distinguishing marks, to dispense with which meant heavy penalties for any member issuing weights on his own responsibility.

A number of excellent photographs accompany Captain Dent's thesis. They include one of a beautiful Cromwellian weight in the author's collection.

Dr. Bidder, of Cambridge, supplies an interesting piece of folk-lore connected with the subject. "A Sussex shepherd is still in old-fashioned villages buried with a lock of wool upon his breast, in order that when he is brought up for judgment on the Last Day, and the Recording Angel reads out the number of Sundays on which he has been absent from church, the lock of wool shall bear evidence of the need of his calling, and he may be forgiven."

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PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES

SCIENTIFIC FOUNDATIONS OF THE REFINING OF PETROLEUM.

By A. E. DUNSTAN, D.Sc. (London), F.I.C., F.C.S.

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V.

CRACKING.

(Delivered January 1928.)

It would be entirely impossible in so brief a review to discuss and describe even the relatively few commercial cracking processes in use to-day. Only to general principles can allusion be made.

Surveying typical examples of cracking processes and the subject in general, there are certain outstanding points of interest. In the first place, the early vapour phase systems, such as those of Noad and Ramage, working under practically atmospheric pressure, were not at all successful in the past; losses were high and the products were difficult to refine. On the other hand, exceedingly high pressure processes have not advanced far beyond the development stage. Most of the methods which have been utilised to any extent operate under comparative moderate pressures. General observations appear to point to the conclusion that, provided the pressure is sufficient to maintain the oil under operation mainly in the liquid phase, there is no particular

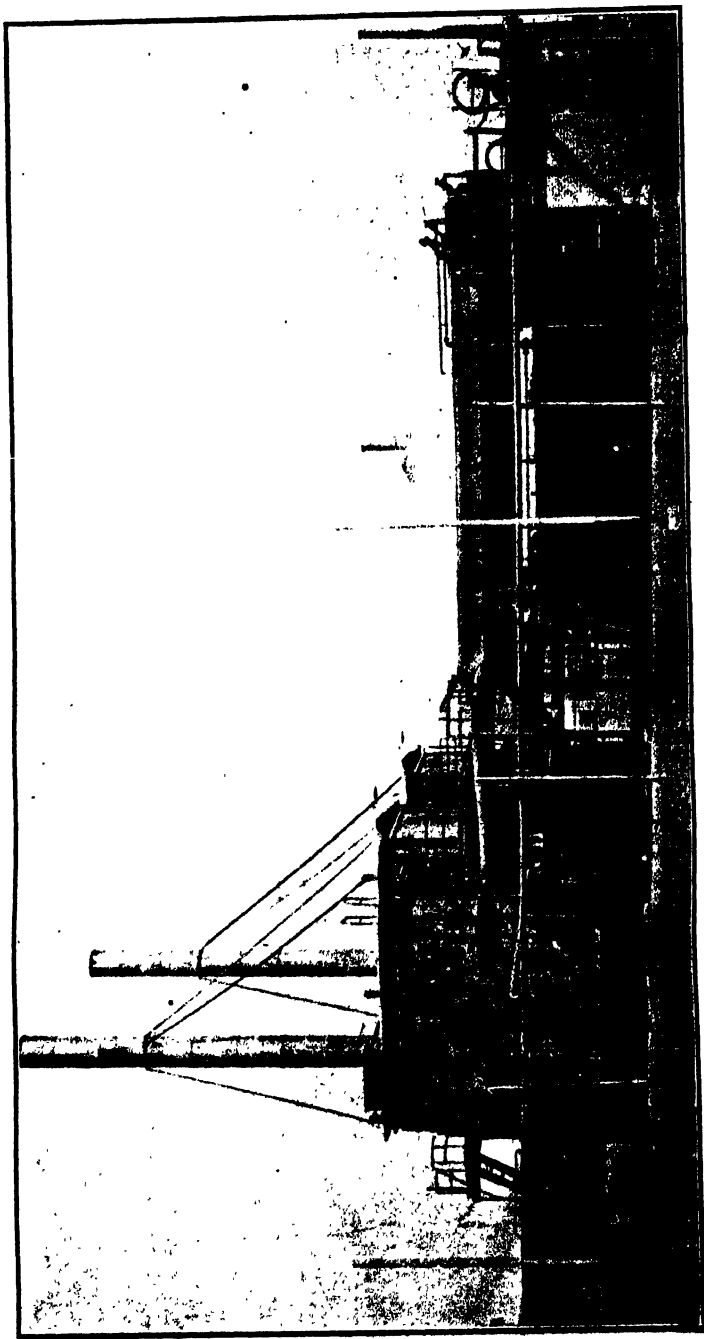


FIG. 29—Cross Cracking Plant, showing the Long Horizontal Reaction Chamber.

advantage in extremely high pressure, as far as the quality of the product is concerned, as oils converted at pressures between 350 and 700 lb. appear to have similar characteristics. Considering extremely high pressure processes like that of Bergius, it is apparent that hydrogenation proceeds, but commercial development is only just being effected.

The question of temperature in liquid phase cracking is decided by the particular oil under treatment and the amount of and type of spirit desired, as there appears to be a definite relationship between the three variables—time, temperature and yield. The percentage of spirit obtained after the oil has reached definite cracking temperature appears to double itself, within limits, for an increase of temperature in the neighbourhood of 10°C . In the same way, when the rate of pumping is halved, or the time of reaction doubled, the same increase in spirit content is noted.

There has not been a great advance in our knowledge of cracking from a chemical point of view during the last few years, and the problems connected with it have been more engineering than chemical. The most urgent problem to the majority of refiners is the elimination—or, at any rate, the diminution in quantity—of coke in order to allow plant to run continuously without having to close down periodically. It is questionable if coke can be eliminated without hydrogenation brought about by one method or another, or by reaction with steam as in the Noad and Ramage processes.

Surprisingly little progress has been made in the examination of the residues left after the cracked gasoline has been removed from the synthetic crude oil. The work of Brownlee (v.i.) may be instanced as an attempt to explore the possibilities of this material, and investigators will do well to bear in mind that in this there is a raw material of unknown constitution, the knowledge of which would probably amply repay intensive research.

The kinetics of pyrolysis still remains in a sketchy and unsatisfactory condition, and it is not surprising that this should be so when it is realised what little exact knowledge we have of the decomposition of even the simplest hydrocarbons. Serious attempts to fill this gap are being made by Professor Wheeler and his co-workers at Sheffield.

Outstanding processes to-day are the Cross and Dubbs, both belonging to the so-called liquid phase type, *i.e.*, with moderate degrees of pressure. The Cross plant is more particularly adapted to cracking of distillate, but the Dubbs method is specially designed for residue oil. The former process operates at about 600-750 lbs. pressure, and the oil, after passing through the heating coils, is held in a horizontal reactor for about fifteen minutes. In the more recent Dubbs plant the heated oil is discharged into heavy vertical reactors at about 200 lbs. pressure. In both processes this product of cracking is cut into residue and distillate by suitable fractioning devices, whilst the Dubbs' plant also can run to distillate and coke only—in this case the

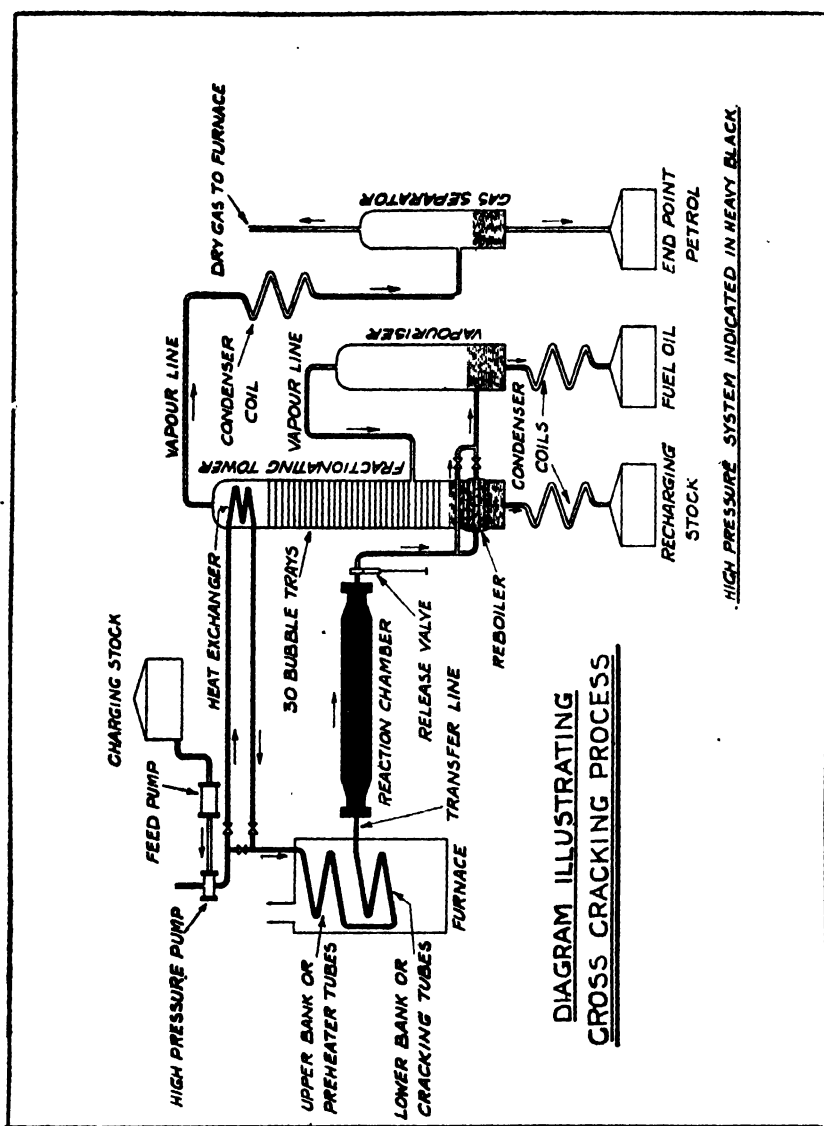
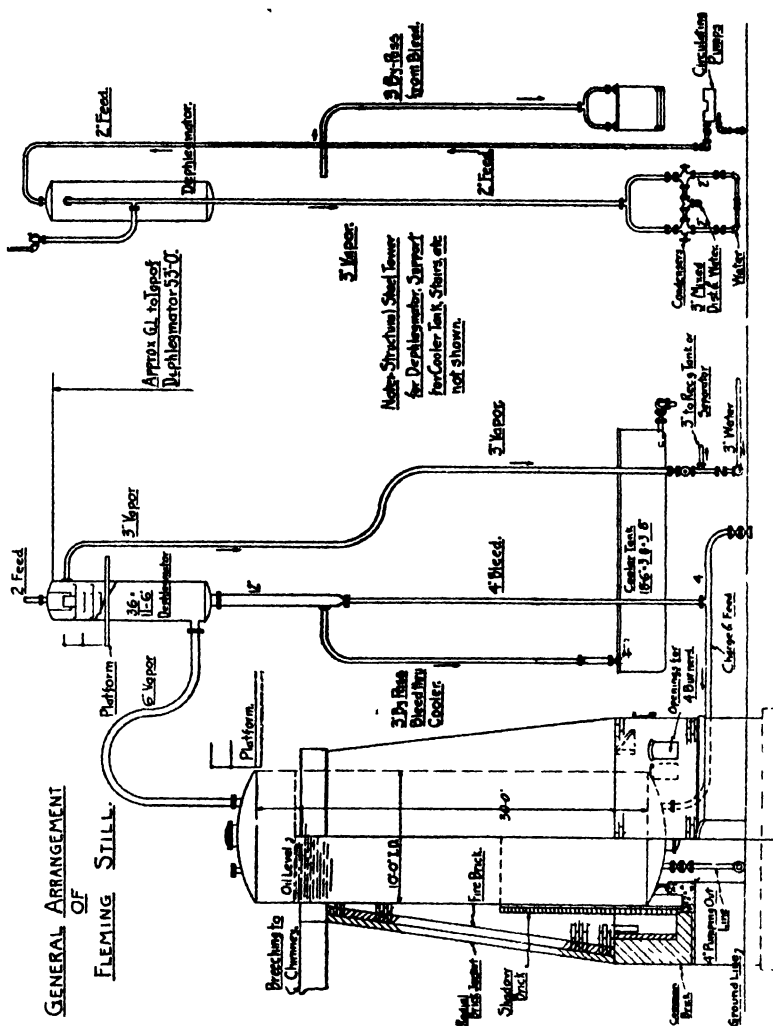


Fig. 30—Cross Cracking Plant.

reaction functioning as a coking still—or, alternating, the heavy product from the reactor may be flashed in a separate vessel.

There are certain fundamental principles in "liquid phase" cracking that should be noted: The pressure should be sufficiently high substantially to maintain the oil passing through the plant in the liquid condition for all but the lightest products; this can be attained by using pressures of the order of 25 to 30 atmospheres. An effect of this pressure is the directing of molecular



scission towards the middle of the molecule, thus limiting the amount of gas and carbon formed.

The yield of light spirit per cycle of operation should be deliberately restricted. This for two reasons :—

- (a) The retention of a considerable mass of the heavier oil helps to hold up the carbon formed and to move it forward to the point most suitable for its deposition; this is especially important when cracking asphaltic residues.
- (b) The greater the extent of decomposition the greater the amount of gas and carbon formed. The reason for this is that the thermolytic decom-

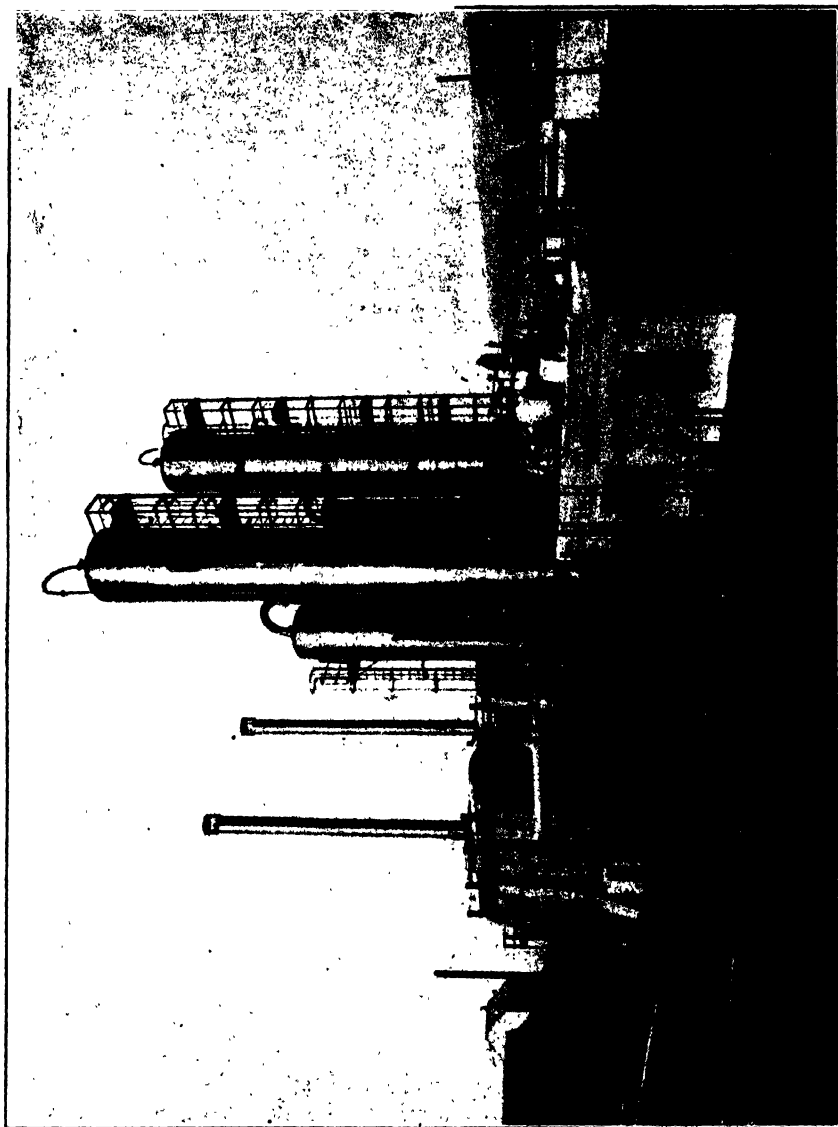


FIG. 32.—Cracking Plant, showing fractionating equipment.

position of a paraffin hydrocarbon appears to proceed along definite lines, and at the best, successive disruption of the paraffin molecules must increase the percentage of unsaturated compounds, or at the worst produce gas and carbon.

For each oil there is a definite and fairly well defined narrow range of temperature at which appreciable decomposition occurs. Above that temperature decomposition rapidly increases.

There appears to be a marked time factor, which is a function of the temperature, governing the spirit. There is an appreciable lag between the moment of attaining the thermolytic temperature and the formation of the products, and the temperature must be maintained for a considerable time if the disruption is to proceed to the maximum extent corresponding to that temperature. It follows that the rate of flow of the oil must be a direct function of the temperature, and controlled correspondingly.

It is impossible to prevent the formation of carbon, and this difficulty must be met by inducing the deposition of carbon in places suitable for its removal. The plant must, therefore, be of the simplest type, with as few bends and corners as possible where carbon can accumulate. Each part must be readily accessible for taking down or for cleaning. Local overheating, which must tend to produce highly undesirable conditions, must be avoided.

Of these modern liquid-phase processes, the Cross, Dubbs, Holmes Manley, etc., it may fairly be said that they are based on the pressure treatment first made practical by Burton, although long foreshadowed by Dewar and Redwood. In all are the integral features of a *heating system* and a *time factor*.

The Bergius process has attracted considerable attention. The early work of Bergius led to the formation of artificial coal from cellulose, wood, etc.; these experiments were intended to reproduce the natural methods of coal formation by variations in temperature and pressure. He was successful in producing a black powder, the carbon content of which was 84 per cent. under a temperature of 349°C. and 160 atmospheres pressure. This substance possessed the properties of ordinary bituminous coal, and on further heating under pressure it passed to the anthracitic type. Bergius discovered that this substance was susceptible to hydrogenation by heating to 400°C. in the presence of hydrogen for some hours, and 70 per cent. of the product was soluble in benzene. In later experiments coal was mixed with oil, and it was found that natural coal was converted to a considerable extent into oil, provided that the carbon content of the coal did not exceed 85 per cent.

The products were of the consistency of thin coal-tar which yielded fractions suitable as fuel oil.

In the cracking of oil by the usual methods gas and coke are produced, the latter being a great hindrance to the continuity of working, and, further, the higher the carbon content of the raw oil the greater is the amount of coke deposited in the cracking plant, and for this reason it is not commercially possible to crack the heavier asphaltic oils or residues to give a high spirit yield. Bergius took up the problem, and stated that practically no coke and very little gas were produced when heavy oils were cracked at a temperature of about 450°C. and 100 atmospheres initial pressure.

The apparatus employed consists of a heavy horizontal steel cylinder (Fig. 33). Inside the cylinder there is a cast-iron vessel, and between them a current of highly-heated inert gas passes as a heating medium.

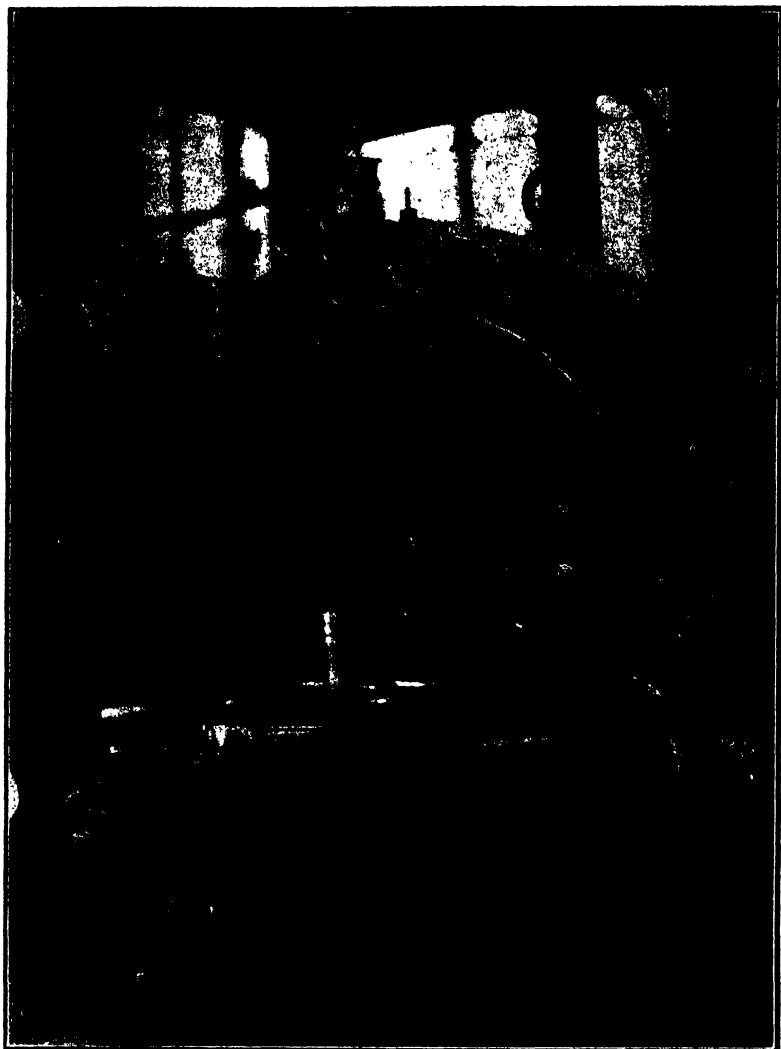


FIG. 33—End view of Bergius Reactor.

Oil and hydrogen are preheated and sprayed into the autoclave continuously and the light products are removed as rapidly as they are formed, the high boiling fractions being returned for further hydrogenation. The heavy residue is continuously withdrawn from the bottom of the vessel. Heat exchangers are arranged for both the out-flowing products and the outer heating nitrogen. The system of heating by means of inert nitrogen reduces the risk of accident, and maintains a temperature which varies not more than 5°C . for weeks.

In the commercial unit the autoclave is thirty feet long and three feet in

diameter, placed on concrete slabs sloping towards the closed ends. It is fitted inside with a stirring device which penetrates to the far end.

The plant is stated to be capable of handling fifty tons per day, and as no carbonisation occurs continuous working for a long period is practicable. The hydrogenation is in most cases accompanied by every little thermal change, but, on the whole, the reaction is believed to be slightly endothermic. The final pressure reached in some cases is as high as 280 atmospheres.

As an example of the operation of Bergius plant a test made on a heavy asphaltic residue may be quoted :—

The properties of the ingoing oil were :

Specific gravity at 15°C.	...	...	...	...	896
Viscosity at 20°C.	...	...	...	—	237 Second Redwood I
Flash point	...	...	...	...	171°F.
Hard Asphalt	...	...	...	...	0.84 per cent.
Sulphur	...	...	...	...	1.02 per cent.

Engler Distillation :

I.B.P.	...	...	...	...	198°C.
Distilling to 250°C.	...	...	...	...	6.5 per cent. by vol.
Distilling to 300°C.	...	...	...	...	27.5 per cent. by vol.

The apparatus was run continuously, and 4,650 kilos of oil were put through.

The yields were :

Distillate	...	...	...	...	84 per cent.
Residue	...	...	...	...	8 „ „
Gas	...	...	...	...	8 „ „

The distillate contained :

Benzine	...	...	...	...	30 per cent.
Kerosene	...	...	...	...	25 „ „
Gas oil, fuel oil, and loss	...	...	...	...	45 „ „

The hydrogen consumption was about 1 per cent. and the benzine, after refining with 1 per cent. acid and soda, was water white and contained 0.07 per cent. sulphur. The kerosene was slightly coloured, and both benzine and kerosene had a pleasant odour. The fuel consumption was about 6.5 per cent., and the gas produced contained about as much free hydrogen as is required for the Berginisation of the oil.

The results of Berginisation do not differ greatly from those of cracking, the chief difference being the difference of gravity in the residue after distillation. The solid paraffin can be almost entirely converted into liquid and gas if time is given. The colour of the Berginised oil is red or yellow, whereas that of the cracked oil is black. Hydrogen is absorbed, the final pressure in the cold being less than the initial pressure and hydrogen has disappeared from the gas. The bromine value is definitely lower for the Berginised oil.

Comparing experiments with hydrogen under high pressure, under low

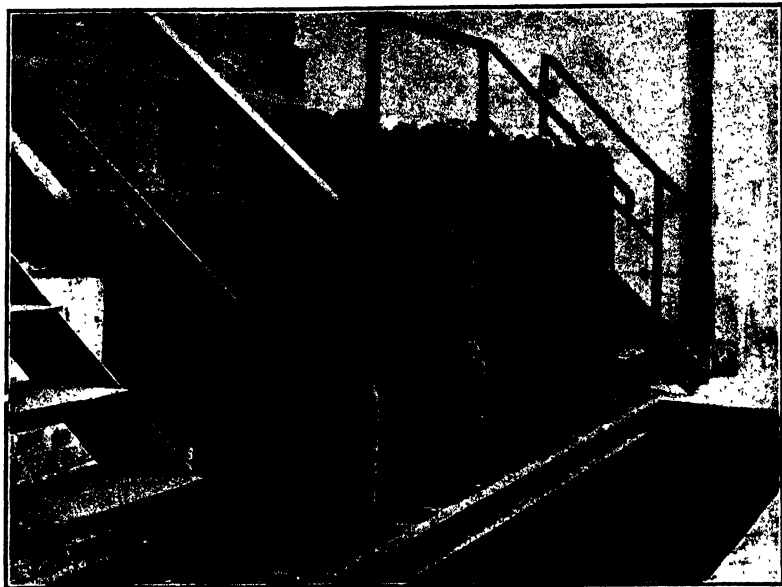


FIG. 34—Experimental Bombs for the Bergius process.

pressure, and in the nascent state with inert gas and with simple heating under autogenous pressure, it appears that the yield of benzine is the same, and that very high pressures are required before hydrogenation takes place. The recent work of Waterman should be consulted in this connection. In Fig. 35 is shown the parallel treatment of wax by cracking and berginisation.

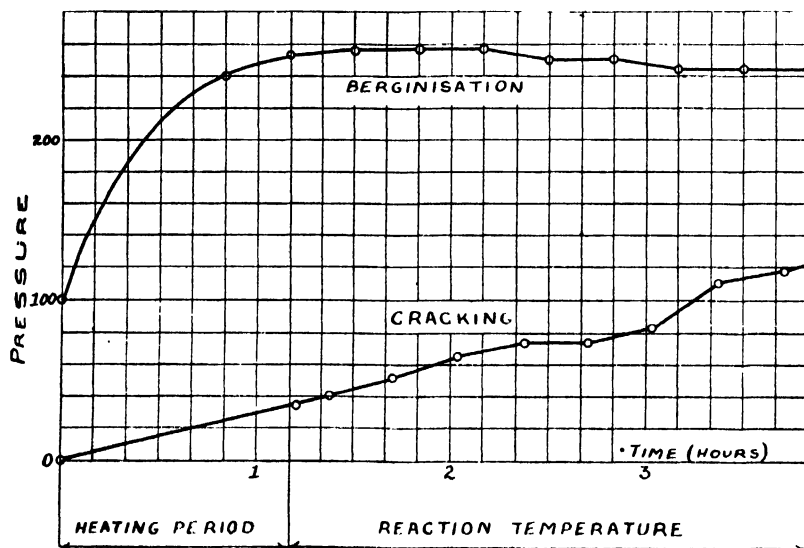


FIG. 35—Comparison between Cracking and Berginisation.

THE REFINING OF CRACKED PRODUCTS.

The difference between straight-run spirit and the product from cracking processes entails a different method of refining, and in order to find a suitable economical process there has been a considerable amount of investigation during the last few years.

The nature of cracked spirit varies, on account of the varying composition of the raw materials and the different conditions under which it is formed. The conditions appear to have more effect than the raw material, and there is one outstanding fact which is impressive, and that is, the difference in the composition of the products obtained by vapour phase and liquid phase processes.

In vapour phase cracking, usually carried out under atmospheric pressure, the product is highly unsaturated and contains compounds which render it difficult to treat with ordinary refining agents. Much of the earlier work, of course, was concerned with this type of spirit, and due to its highly unsaturated nature large amounts of gum were deposited on standing. Refining methods for this spirit were drastic; losses were great, and the final products were of inferior quality. The treatment of liquid phase cracked spirit is more simple, and numerous methods have been devised which result in the production of water white gasoline of inoffensive smell.

It is noticeable that the liquid phase cracked spirit produced by various methods is similar in general behaviour, whatever the original stock employed, except in the sulphur content, which is, to a great extent, directly proportional to that of the raw stock.

The freshly-distilled spirit is almost white, but acquires colour on standing, becoming brown and slowly depositing a reddish-brown gum. This gum is different in character from the typical gum of a vapour phase cracked oil. It is granular instead of liquid, the quantity is less, and in appearance is similar to the polymerised product formed when kerosene is exposed to light and air. The colour is different, having none of the light yellow shade so characteristic of vapour phase cracked spirit.

The total loss to sulphuric acid (100 per cent.) in the case of a liquid phase spirit from Persian residue was 22 per cent., and from American gas oil 25 per cent. A vapour phase cracked spirit lost over 70 per cent. with the same treatment.

Various refining agents have been proposed for the purification of these spirits, including silica gel, aluminium chloride, bauxite, fuller's earth, etc.

Plain filtration through contact agents such as bauxite, silica gel, etc., does not give a satisfactory result.

When cracked spirit is slowly distilled over small quantities of crushed anhydrous aluminium chloride the distillate, after washing with soda to remove hydrochloric acid, is of good smell, water white and stable. The process is simple and effective. Unfortunately, the non-volatile polymerised bodies formed in quantity in the still are very resinous and deposit on the walls as a

sticky mass difficult to remove and involving loss of aluminium chloride. So far these inherent difficulties have not been overcome. Recovery of aluminium chloride is also difficult, and the operation, therefore, likely to be expensive.

The use of anhydrous zinc chloride for refining cracked spirit has also been patented, and its action is similar to aluminium chloride, much less drastic, but the problem of refluxing or distilling over this solid is the same.

A modification of this process wherein the zinc chloride was mixed with an equal quantity of zinc dust showed a limited saturation effect and considerable mechanical advantage, for the mixture remained dry and could be handled with an ease impossible with the zinc chloride alone. Polymerisation is slower and more even. The distillates were colourless and of good smell.

When cracked spirit at ordinary room temperature is mixed with bauxite, floridin, activated charcoal, or other porous materials of a similar nature, polymerisation of the most unsaturated compounds present takes place with evolution of heat. The reaction proceeds more vigorously if the contact material is maintained at an elevated temperature and if kept at a few degrees above the final boiling point of the liquid, so that the reaction takes place in the vapour phase, the products of polymerisation are retained in the contact material, and a colourless, sweet-smelling condensate is obtained which has lost its tendency to form gums. In this operation the contact material becomes clogged with the polymerised gum, which is difficult to remove and may cause choking of the filters. It has been found that by working at about 100°C., and thus maintaining the spirit substantially in the liquid phase, polymerisation takes place equally as well as in the vapour phase. The polymerised products, however, are washed out by the oncoming material, and by this means the contact material is kept clean and free to continue work for a longer period than would otherwise be the case. On issuing from the filters the spirit is of a much darker colour than originally, since it contains the original volatile gum-forming constituents dissolved in the form of non-volatile gums. By means of a simple distillation therefore, the latter are left behind in the still, and a colourless, sweet-smelling and non-gumming product is obtained.

The contact material can be steamed out and roasted, and is then ready for further use. This part of the process is identical with that in use for recovering bauxite after kerosene filtration, and presents no difficulties. In the Gray process the vapours of the cracked spirit pass through a drum of fuller's earth, leaving behind the polymerised gummy matter. The earth can be removed by appropriate roasting.

The result of the treatment is to lower the amount boiling below 100°C. by about 2 per cent., as compared with the untreated material, but otherwise the boiling points are identical. Using bauxite the sulphur content is reduced from about 0.3 per cent. to about 0.15 per cent., but the product remains quite stable for many months without gum formation or reversion in colour.

Cracked spirits treated with strong sulphuric acid give acid tars in a quantity

that varies with the unsaturation of the spirit and the amount and concentration of the acid used. The spirit undergoes loss both by actual removal of unsaturated and polymerised bodies, and by the raising of its boiling point by polymerisation of some of the compounds present. After redistillation the spirit can be obtained water white and non-gumming and with a lower sulphur content. The smell is altered and is peculiarly terpenic in character. Ordinary American practice is to use 1 per cent. or 2 per cent. of sulphuric acid, but with inferior products more is needed to give the desired results. The losses are then proportionately greater and the peculiar smell of the spirit more marked.

During the acid treatment alkyl sulphates are formed, and these cannot be removed by soda washing, and, if left in, may cause the subsequent reversion of the spirit. They may be removed by distillation, but during distillation they decompose and sulphur dioxide is formed.

The effect of different proportions of acid has been investigated and samples have been treated with $\frac{1}{2}$ per cent., 1 per cent., and 2 per cent. respectively of acid. The sulphur content was reduced in direct proportion to the amount of acid used, the original percentage of sulphur being .102, $\frac{1}{2}$ per cent. acid reduced this to 0.06%, 1 per cent. to .04%, 2 per cent. to .02%. Sulphur dioxide is formed in the redistillation of the treated spirit, and the greater the treatment the greater the amount of the gas that is evolved. This effect takes place about 130° to 140°C., and is accompanied by darkening of the liquid due to the separation of a finely divided carbonaceous solid.

An original method of treating cracked products has been patented by R. H. Brownlee, whereby oil of high flash point, high viscosity and low cold test is obtained by polymerisation of a light unsaturated oil, such as gas oil from synthetic crude, by agitating it with a catalyst at 200° to 400° F. Aluminium chloride, or reagents which will produce a similar halide, are suggested.

The light hydrocarbon is purified by treatment with sulphuric acid and then acted on by the catalyst in a vessel provided with an agitator and a heating coil. In about 1½ hours the action is complete and the sludge is allowed to settle off. The oil is cooled, soda treated to precipitate colouring matter and washed with water, then distilled with the aid of steam.

The distillate includes products of the nature of naphtha and kerosene, but more particularly a series of lubricating oils that have a very low cold test.

In view of the more recent work on the mechanism of hypochlorite refining the possibility of using hypochlorites for treating cracked distillates has been investigated. Modern requirements do not demand such drastic refining as hitherto; sulphur content is no longer the primary criterion, low gum formation and stability being of greater importance. The colour of the finished product, if reasonably good, need no longer be water-white.

A common procedure in the States is to sweeten by means of sodium plumbite and then give an acid wash. After the acid treatment, which effects polymerisation of the reactive hydrocarbons, and at the same time partial desulphur-

isation, the distillate is washed with water, with soda, and, finally, again with water. It is then re-run to the correct end point and the refining completed by a small wash with dilute soda. The sulphur content of spirit refined in this way is not necessarily low, but the products possess a not unpleasant odour and are reasonably stable.

It has been found that under the correct conditions hypochlorite solutions can be used as a sweetening agent. In the second lecture (p. 49) it was explained that of the sulphur compounds present in straight run distillates, the mercaptans and the lower sulphides are readily oxidised by alkaline hypochlorite solutions. The sulphides, however, possess in dilute solution a not disagreeable odour and are not responsible for the "sourness" of the unrefined distillate, which is due to hydrogen sulphide and the mercaptans. If, therefore (after the hydrogen sulphide has been removed by a preliminary soda wash), it is possible to convert the mercaptans to the "sweet"-smelling disulphides by means of alkaline hypochlorite, the whole benzine should be quite "sweet," although not necessarily low in sulphur. At the same time, it is important that simultaneous chlorination of the hydrocarbon constituents should not occur. It was explained in the section on "hypochlorite treatment" that the concentration of free hypochlorous acid in a hypochlorite solution is diminished by the addition of free alkali. The use of alkaline hypochlorite (*i.e.*, hypochlorite solution to which free alkali has been deliberately added) should not, therefore, involve formation of chlorohydrins, *i.e.*, and should not cause "chlorination" of the oil. The use of alkaline hypochlorite would, therefore, be expected to "sweeten" a soda-washed cracked distillate without causing "chlorination," provided the sourness is due to the same cause as the sourness of a soda-washed straight-run distillate, that is, to mercaptans. This expectation has been realised. To prevent waste of hypochlorite, the amount used is so adjusted that it is only sufficient to effect sweetening without much desulphurisation. If, after sweetening, the distillate receives an acid wash, polymerisation of the reactive, gum-forming hydrocarbons occurs and simultaneously partial desulphurisation is effected by extraction of some of the sulphur compounds. After soda-washing and re-running (using ample steam), a final soda wash on the distillate (using 0.5% soda, because stronger soda might tend to cause further polymerisation), gives a marketable spirit water-white in colour, possessing a pleasant odour and low gumming propensities and having a sulphur content varying with the acid treatment given. Thus, in parallel experiments, using $\frac{1}{2}\%$ and 1% acid respectively, the sulphur contents of the finished products were 0.06% and 0.035%; it was found during this work that the acid treatment determined the sulphur and gum contents and that the hypochlorite had little effect on the total sulphur content.

A vitally important point in the refining of cracked spirit is the effect of the treatment on the capacity of the spirit to withstand detonation in the engine. The "gum-forming" compounds are possessed of high anti-knock properties,

and therefore it should be the aim of the refiner to give the minimum treatment compatible with merchantable properties.

SYNTHETIC PRODUCTS FROM PETROLEUM.

Although it has long been known that petroleum yields excellent starting materials for the synthesis of organic compounds, it is only recently that any of these substances have been prepared from it on a large scale. At the present day large quantities of alcohols are produced yearly in America from the gases that are evolved in cracking, and this production is on the increase. Other compounds are produced besides alcohols, such as amyl chlorides and esters, but they are all from the lower or gaseous fractions. No use has so far been found for the high fractions, although during the war T.N.T. and other nitro-bodies were produced from the gasoline fraction to a very considerable extent.

Only two sources have therefore to be dealt with at present, that is to say, gases from cracking plants and the lighter components of gasoline.

GASES FROM CRACKING:

Gases from cracking are by far the most important source for synthetic alcohols. At present America is the only country producing alcohols in this manner, although pioneer work has been carried out in Europe, particularly on the conversion of ethylene into ethyl alcohol. The growing importance of cellulose-derived varnishes and lacquers makes it all important to secure ample supplies of solvents manufactured from the alkylenes that are produced in cracking.

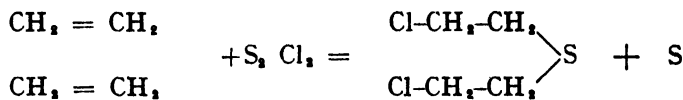
Gases from cracking vary very considerably in composition according to the type of cracking, the cracking stock and the pressure and temperature conditions. Of these variables temperature is by far the most important.

Liquid-phase cracking at temperatures *circa* 450°-480°C. produces a gas containing only a comparatively low content (8-13%) of unsaturated hydrocarbons, whereas vapour phase cracking at temperatures of 600°C. and over produces a gas having from 30 - 75% unsaturated hydrocarbons. The composition of this unsaturated content also varies considerably with the type of cracking; the same gases are usually found in both types but in different proportions. Thus, liquid-phase cracking produces relatively little ethylene and only a trace of diolefines; the vapour phase gas may contain 25% ethylene and sometimes over 2% of diolefines. The high ethylene content of the latter gas indicates the possibility of using it as a source of this material for the preparation of gases for war purposes.

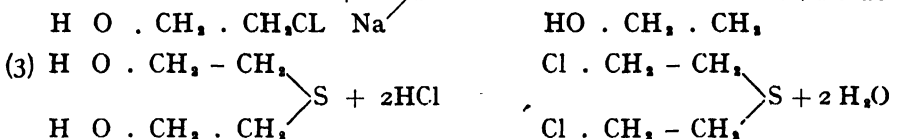
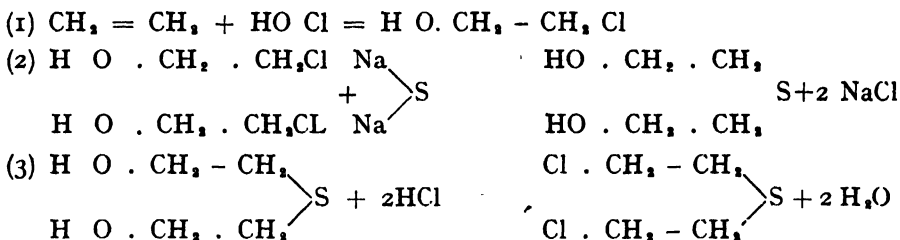
ETHYLENE

Ethylene is the starting material for mustard gas both in the method worked out for the Allies by Pope as well as in the original German method. The scheme of preparation is given below ;—

POPE'S METHOD.



GERMAN METHOD.



Ethylene itself is an excellent anæsthetic, and has the advantage over ether and chloroform of producing no depressing effect on the heart. Propylene is a better anæsthetic than ethylene, but it polymerises on standing. Ethylene has also been used in the artificial ripening of fruits.

Ethylene dichloride is used as a solvent and as a fumigant for grain. It is the intermediate in the manufacture of ethylene diamine, which is applied as an accelerator of vulcanisation. Ethylene chlorhydrin is an important intermediate in the manufacture of novocaine, procaine and indigo. Ethylene oxide on treatment with alcohol gives the monoethyl ether of ethylene glycol, which is an excellent solvent for cellulose derivatives.

COMPOSITION OF GASES FROM CRACKING.

The substances generally present in the gas include ethylene, propylene, butylenes, amylenes, higher olefines and butadiene. Few authentic analyses appear to have been published.

The following figures may be quoted for an analysis of the unsaturated content (*i.e.*, 55.75% of the total gas) in a vapour phase cracking operation.

Ethylene	...	...	...	54.0	per cent.
Propylene	...	...	...	28.0	„
Butylene	...	...	...	9.0	„
Amylene	...	...	...	1.7	„
Higher Olefines	...	...	...	6.1	„
Butadiene	...	...	...	1.2	„

Propylene appears to form an important constituent of the unsaturated hydrocarbons in all similar gases.

EFFECT OF TEMPERATURE.

The effect of temperature of cracking on the relative proportions of ethylene and propylene has not so far been recorded but Brooks give the following table for the composition of oil gas, which is, of course, a vapour phase product.

TABLE XXVI.

Temp. °C.	Higher Olefines.	%C ₃ H ₆	%C ₄ H ₄	Total Olefine Content.
805 - 650	1.4	18.6	16.3	36.3
660 - 535	1.6	19.0	18.3	38.0
635 - 535	2.4	22.4	12.5	37.3
625 - 535	2.6	22.6	13.7	38.5
615 - 425	3.6	25.7	12.0	41.5

In other experiments the analyses were obtained of the oil gas produced by rapidly passing gas-oil vapours, under pressure, through steel tubes heated to certain definite temperatures.

TABLE XXVII.

Temperature °C. ...	...	...	600	650	700	730
Pressure, lbs./sq.in. ...	...	...	57	72	83	95
Ethylene % ...	...	...	19.3	19.6	17.7	17.5
Propylene % ...	...	...	28.0	28.4	23.9	20.0
Higher Olefines % ...	...	...	2.3	4.2	3.5	3.1
Total Olefines % ...	...	...	50.5	51.6	45.1	40.6

Although the total olefine percentage is less at a higher temperature, the net yield is considerably greater on account of the greater volume of gas produced (cf. next table).

TABLE XXVIII.

Temp. °C.	% Gas.	% C ₂ H ₄ & C ₃ H ₆ .
605	17.7	47.9
625	26.6	46.1
645	37.6	44.9
665	40.0	43.7
685	40.8	42.6
705	48.7	29.5
725	66.6	38.5

The quantity of gas produced is determined by the type of cracking. Normal vapour-phase cracking produces, roughly, the same yield of gas as of spirit, but if the temperature is increased to 700° or higher, the yield of gas can be increased so that the yield is much higher than the yield of spirit. It is therefore quite possible that cracking solely for gases might pay; even after the valuable olefines have been removed, the residual gas has a high fuel value.

PRODUCTION OF ALCOHOLS.

The chief alcohols produced from alkylenes at the present time are isopropyl and secondary tertiary butyl alcohols. Ethyl alcohol does not appear to have been produced commercially, although the method of preparation has been worked out by Gerr. and Popov (*Nefthanoë Chozjstvo*, 1926, 10, 88). It has, however, been stated that alcohols as high as decyl alcohol will soon be on the market in reasonable quantities.

The chief work on the preparation of the alcohols has been done by H. S. Davis, of the Petroleum Chemical Corporation, and is described in English patents 248375 and 249834. Numerous other investigators have studied the reactions involved. Reference should be made to the work of B. T. Brooks and his colleagues (See also the *Non Benzenoid Hydrocarbons*, Chemical Catalog Co., New York. 1922).

Briefly the process is as follows :—Desulphurised gas from the cracking plant is passed up absorption towers counter current to a descending stream of sulphuric acid. The towers are constructed on the bubble cap principle. A certain amount of heavy oil is introduced together with the acid, as this assists in producing a condition of foam, and therefore assists the reaction between the acid and unsaturated gases. Following the towers is a spray catcher. The acid is settled, polymerised diolefines removed, water added until the specific gravity falls approximately to 1.2 or 1.3 further oily polymers run off, if necessary, and the aqueous solution distilled. The alcohols are then rectified.

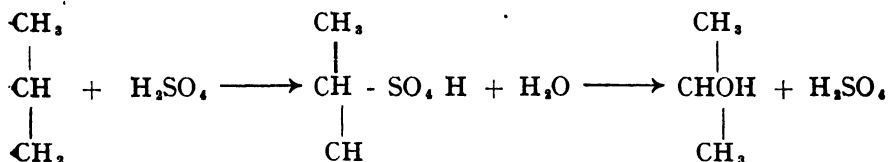
In order to separate the various unsaturated constituents of the gas graded strengths of acid are employed. 75% - 83% acid is first employed to remove the higher olefines followed by 93% - 100% acid, which absorbs the propylene. The temperature of the acid used to absorb the propylene is important and must be below 30°. Ethylene can only readily be absorbed at higher temperatures, Absorption is allowed to proceed until the gravity falls to a figure corresponding with the lower limit of acid concentration.

In the first patent taken out by Davis (E.P. 248, 375) the method for preparing the tertiary and secondary alcohols is described. In accordance with this method a preliminary separation of the gases leaving the plant (the use of vapour-phase cracking gases is advocated) is effected by scrubbing with cooled gas oil. The gas escaping from the scrubbers contains ethylene and propylene, the latter being readily converted into isopropyl alcohol by the procedure described in the second patent, *i.e.*, solution in 100 per cent. sulphuric acid below 30°C., dilution and distillation to afford the isopropyl alcohol. The gas oil from the scrubbers passes into a still whence the butylenes and amylenes are recovered. By suitably adjusting the temperatures and the pressures, the amylenes (b.p. 21°-40°) are condensed. The butylenes are collected for treatment as gases. The method employed for the production of tertiary alcohols consists in washing the butylene and amylenes fractions

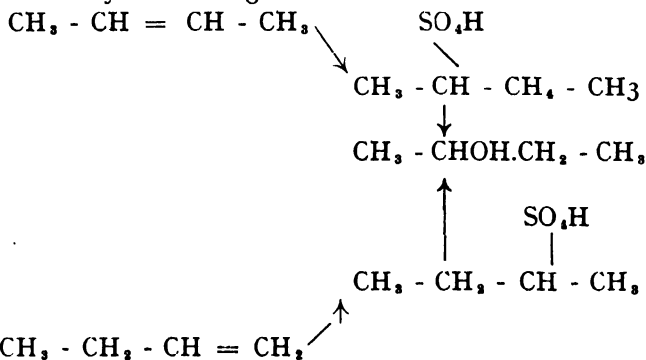
with 60 per cent. acid. This procedure brings about solution of the *iso*-hydrocarbons only. After careful neutralisation with lime the aqueous layer is distilled when the *tertiary* alcohols collect. The residual hydrocarbons are treated with stronger acid, the acid layer diluted and distilled to recover the *secondary* alcohols.

Vanadic acid or silver sulphate can be added to the acid as catalysts.

In this way *isopropyl* alcohol is readily obtained.



The normal butylenes both give the same alcohol thus :—



Isobutylene gives *tertiary* butyl alcohol, but the method employed to separate this alcohol is not at all clear, because the alcohol readily loses water to regenerate the hydrocarbon when treated with quite dilute acid.

Isopropyl ethylene gives no alcohol but only the dipolymer $[\text{C}_5\text{H}_{10}]_2$.

PROPERTIES.

The secondary and tertiary alcohols are very valuable solvents, the latter being miscible with water in all proportions and quite inert to oxidising agents. The boiling points are lower than the corresponding isomers.

Isopropyl alcohol has found use as an antiseptic capable of replacing alcohol. It is not corrosive and is a stronger germicide than ethyl alcohol.

GLYCOLS AND CHLORHYDRINS.

Glycols are the compounds intermediate between glycerol and alcohol; they share with glycerol the properties of mixing with water in all proportions and of having little, if any, effect on rubber. Like glycerol, they lower the freezing point of water. These properties render them ideal for use in radiators

in cold climates as "anti-freeze" compounds. A 10 per cent. aqueous solution of glycol freezes at -2°C .

They are commonly produced by means of the dichlorides which are converted into acetates and hydrolysed, but with poor yields. They may be obtained by heating the chlorhydrins, produced by the interaction of the olefine and dilute hypochlorous acid (of Brooks E.P. 128, 578, 1919) in aqueous solution with sodium bicarbonate under pressure to 105°C . Care must be taken not to use stronger alkalis if the formation of the alkylene oxide is to be avoided.

The chlorhydrins find uses as solvents in industry both as such and as chlorhydrin esters. There is little mention in the literature of propylene glycol excepting that difficulty has been experienced in separating it from the lower homologue by fractionation.

Diethylene Glycol $\text{OH}\cdot\text{CH}_2\cdot\text{CH}_2\cdot\text{OH}$ is a colourless, odourless liquid boiling at 245°C . It is considerably more hygroscopic than glycerine, and for this reason has been used in the manufacture of materials such as composition cork and parchment paper that must be kept pliable over a long period of time. It has been used as a lubricant in the spinning of textiles and in the coning of silk. Unlike glycerine, diethylene glycol is an excellent solvent, and will dissolve nitrocellulose, resins, and many organic liquids.

The hydroxyl groups can be replaced by other radicals to yield such products as glycol mono ethyl ether, a nitrocellulose solvent or glycol dinitrate, which has been used as an explosive, replacing nitroglycerine because of its lower freezing point and greater resistance to shock. Ethylene dichloride can be condensed with benzene in the presence of aluminium chloride to yield dibenzyl, which on gentle oxidation yields the important intermediate benzaldehyde. Glycol and its congeners and derivatives are bound to play a valuable part in synthetic chemistry.

DIOLEFINES.

At present there is no use—other than for the possible preparation of synthetic rubber-like polymers—for butadiene, which forms an appreciable quantity of the gas, although O. Aschan has indicated the utilisation of this group of hydrocarbons.

NATURAL GAS GASOLINE.

This product contains considerable quantities of pentane and *isopentane*, which are now being separated and marketed by the Sharples Corporation. They are also producing a wide range of products from them which include not only all the known amyl alcohols, but also amylene dichlorides and amyl chlorides.

The alcohols are produced by chlorination of the parent hydrocarbons, conversion to acetates by means of sodium acetate, hydrolysis and fractionation of the alcohols. The products are of reasonable purity and find a ready market.

The following are among the products of the Sharples Corporation :—

n - butyl carbinol.
iso butyl carbinol.
 methyl propyl carbinol.
 diethyl carbinol.
ter butyl carbinol.
 amyl chlorides (mixed).
 pentane.
iso pentane.
 amylenes.
 amylene dichloride.

There is a description of the plant for the chlorination of pentanes used by the Sharples Solvent Corporation in a recent paper (Chem. Met. Eng. 1927, **34**, 276). The hydrocarbons are mixed in the gaseous state with chlorine and forced into the chlorination vessel under pressure. Hydrochloric acid is produced and is recovered. The chlorination mixture, which contains all the possible monochlorides with the exception of two (the *tertiary* amyl chloride and the *secondary iso* chloride), is hydrolysed by the theoretical amount of caustic soda and the alcohols are fractionated.

The thermal treatment of gases for synthetic products has already been discussed (p. 19), but brief reference should be made to the possibilities of working up the mixture of carbon monoxide and hydrogen that is produced by the action of steam on methane.

The Badische Anilin und Soda Fabrik early discovered that liquid products resulted by contacting a mixture of carbon monoxide and hydrogen with a variety of catalysts at temperatures of the order of 400° C. and pressures of 120 atmospheres (G.P. 293,787, 1913). This discovery was the prelude to a series of researches which have shown that a large variety of products can be obtained when carbon monoxide is caused to react with hydrogen under varying temperatures and pressures and in presence of different catalysts. Work by the Badische Company was interrupted, partly by the war, and partly by the fact that the heterogeneous nature of the products was thought to militate against the commercial exploitation of the new process. The results, however, laid down the lines on which later researches should be carried on, the objective being the production of methyl alcohol. Simultaneously, Patart, in France, was investigating the same series of reactions and caused to be erected in 1922 a small-scale plant in which the required material was successfully prepared, while the B.A.S.F. a little later began the actual manufacture of methanol on a commercial scale. On the other hand, Fischer and Tropsch, at the Institute of Coal Research, Mulheim-Ruhr, returned to the reaction originally investigated by the B.A.S.F., their object being the preparation, not of methyl alcohol, but of substances which would serve as substitutes for motor spirit. As a result of their experiences in this work, the latter investigators proceeded a step further, and actually synthesised a product which

consisted entirely of hydrocarbons—gaseous, liquid and solid—and virtually established the possibility of synthesising petroleum, starting with coal and water.

The reactions which water-gas can be made to undergo are, therefore, many and varied, and since the work is only yet in an early stage, the ultimate possibilities are of extreme interest.

The processes of the Badische Company (E.P.s 227,147, 228,959, 229,714, 229,715, 1923; 231,285, 237,030, 240,955, 1924), and of Patart (*Compt. Rend.*, 1924, 179, 1330-2; *Chem. et Ind.*, 1925, 13, 179-185; see also Lormand, *J. Ind. Eng. Chem.*, 1925, 430-2) are not radically dissimilar in principle. Whilst the former prefers as catalysts metallic oxides or their mixtures, especially the oxides of copper, silver, zinc, lead and cadmium; the latter specifies all the metals, oxides or salts which are known to favour oxidation or hydrogenation, such as the oxides of vanadium, chromium and zinc, preferably mixed with copper, and such salts as chromates, manganates, vanadates, molybdates and tungstates. In both cases metals of the iron group—iron, nickel and cobalt—must be rigorously excluded, the B.A.S.F. even carrying this restriction so far as to preclude such metals as components of any hot portion of the plant whilst, also, the reacting gases contain hydrogen in excess (1.5 to 2 volumes of hydrogen to one volume of carbon monoxide). With regard to other experimental conditions, the B.A.S.F. carefully purifies the gases before interaction, whereas Patart effects only partial purification in a single scrubber; Patart however works at pressures of 500 atmospheres and the Badische process at about 200 atm. Temperatures in each case approximate to 400° or 420° C.

Patart's experimental plant gave a conversion of gas to liquid of from 8 per cent. to 10 per cent. with one passage of the gas, and he further estimated that 100 litres of methyl alcohol can be produced from 300 cu. metres of water-gas at a cost of 25 to 30 gold francs.

Fischer, who has carried out experiments on the same lines, found that equal volumes of carbon monoxide constituted the most suitable mixture to be operated on, that zinc oxide was the best catalyst, and that iron, nickel and cobalt were detrimental to the course of the reactions. At temperatures and pressures of 400° C. and 150 atm. respectively the yield of methanol was almost theoretical, the crude product containing only traces of acids, and containing 93 per cent. of constituents boiling below 80° C. The zinc oxide was still pure white, after use extending over some weeks.

Synthetic methanol is now a recognised article of commerce, and finds extensive use in many directions; as a motor fuel, however, it is not a success. Its calorific value is low, and its lack of capacity for resisting pinking in the engine will prevent its adoption, for this purpose, on any large scale.

SYNTHOL.

It was probably for these reasons that Fischer and Tropsch began to investi-

gate the original Badische process by which liquid hydrocarbons were stated to have been obtained. In their first experiments, they repeated exactly the conditions specified in German Patent 293,797, 1913, Example 2, *i.e.*, purified water-gas containing an excess of hydrogen was passed at 400° to 420° C. and 90 atm. pressure over a catalyst consisting of alkali and zinc carbonate on pumice, but the original gas emerged practically unchanged, and not a trace of oil was obtained (*Conversion of Coal to Oil*, p. 221). Subsequently it was found that, whereas in the preparation of methanol, iron group metals are definitely inhibitory, their presence if other products are required is essential, and at the same time the simultaneous use of strong alkalis is necessary. In short, if water-gas is passed over a catalyst composed of iron borings impregnated with a strong base in the form of a hydroxide or carbonate, the temperatures being 410° C. and the pressure 150 atm., the reaction product consists of watery and oily layers. The oily components, known as synthol, contain no hydrocarbons, but are composed of a complicated mixture of higher alcohols up to C₁₁, of fatty acids to C₈, and of aldehydes, ketones and esters. The proportion of this product can be increased by using strong bases, *e.g.*, rubidium carbonate, by having a greater thickness of catalyst, and by operating upon a gas mixture containing a less proportion of hydrogen.

SYNTHETIC PETROLEUM.

The work briefly described in the preceding sections indicates that catalytic reduction of carbon monoxide at high pressures leads to the formation of oxygenated compounds, whereas at atmospheric pressure and a high temperature methane is the sole product. Investigating the latter reaction more thoroughly, Fischer and Tropsch elicited the fact that it is possible to obtain products fundamentally different from those previously obtained, and that the reduction of carbon monoxide can be effected at quite low temperatures. For example (*Brenn. Chem.*, 1926, 7, 97-104), they describe the formation, from water-gas, of homologues of methane, consisting of a series of gaseous, liquid and solid hydrocarbons, the heaviest of which have 70 carbon atoms in the molecule. The most effective catalysts are iron, cobalt and nickel, mixed with a small proportion of the oxide of the same metal, though many other metals or oxides may be employed. The optimum temperatures are 300° C. with iron, 270° C. with cobalt, and 160° C. with nickel. Although it is usual to operate with carefully purified water-gas, successful results have been obtained with mixtures corresponding to generator gas and furnace gases.

The product, as stated above, consists of water, carbon dioxide and hydrocarbons, the lighter portions of the latter passing away from the catalyst tube to condensers and scrubbers, whereas the heavier fractions, including solid hydrocarbons, collect in and around the catalyst and eventually prevent it from functioning. Consequently the contact material has to be steamed periodically. It has also been found that the addition of a little alkali to the

catalyst increases the molecular weight of the resulting hydrocarbons. Thus, already, it is known that the boiling range of the product can be varied.

The researches on the synthesis of hydrocarbons have not yet progressed to the extent that an opinion can be expressed as to the probable commercial value of the chemical reactions involved. Their scientific importance, however, is enormous, and the results which have accrued in a relatively short space of time in working with such an apparently unpromising material as water-gas are encouraging, and must stimulate further researches in the realm of fuel technology.

OXIDATION REACTIONS.

Brief reference should be made to the possibilities of synthetic reactions based on oxidation. The bulk of the investigations have hitherto been confined to aromatic hydrocarbons and, for example, mixtures of air and toluene have been passed over a variety of catalysts.

Of the contact agents studied, vanadium oxide has been most popular, and it is a matter of considerable interest to note that this material is a very common component of most petroleum ash. Maleic acid, quinine, benzaldehyde, benzoic acid, diphenyl, phthalic acid have all been made in this way.

Formaldehyde has been synthesised from methane in the presence of ozonised air, whilst hexane yields aldehydes and acids up to the sixth members of the series. Fatty acids of the higher molecular weight have been obtained by oxidising paraffin wax.

Although the way to the further utilisation of petroleum as a synthetic material is thus being rapidly opened out, it is clear that very intensive research is needed to develop a great industry similar to that based on coal tar. The chemistry of the aromatic compounds has been described as a "facile chemistry." This reproach can never be levelled against the new petroleum chemistry, but, although research will be difficult, and will need a new technique of separation, the prospects are wider and the scope illimitable.

The author's thanks are tendered to the Chairman and Directors of the Anglo-Persian Oil Company in whose laboratories the experimental work described in this discourse was carried out and to the President and Council of the Royal Society of Arts for honouring him with the invitation to deliver this series of Cantor Lectures.

NOTES ON BOOKS

INTRODUCTORY HANDBOOK TO THE STYLES OF ENGLISH ARCHITECTURE. By Arthur Stratton. London: B. T. Batsford, Ltd.

In the notice of this handbook published in the *Journal* on August 10th, the price was incorrectly stated. The price is 1s. 6d. net for the paper edition, 2s. 6d. net for the cloth. The accompanying architectural diagrams are 1s. 4d. each, or 2s. 10d. mounted, the price of the complete set of 13 diagrams being 13s. unmounted and 32s. mounted.

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*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C.(2.)*

NOTICE.

COMPETITION OF INDUSTRIAL DESIGNS.

LOCAL EXHIBITIONS.

The exhibition of industrial designs at the Imperial Institute, which was viewed by a large number of visitors during the month of August, closed on September 1st. Arrangements have been made this year, as on several occasions in previous years, for holding local exhibitions of particular sections of the designs in provincial centres after the end of the exhibition in London. Two such local exhibitions have been arranged this year—an exhibition of the china and earthenware designs from September 18th to October 1st at the Burslem School of Art, and an exhibition of the glass designs from September 24th to 26th at the Wordsley School of Art.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES

FATIGUE PHENOMENA, WITH SPECIAL REFERENCE TO SINGLE CRYSTALS.

By HERBERT JOHN GOUGH, M.B.E., D.Sc., Ph.D.
(Engineering Department, National Physical Laboratory, Teddington.)

I.

(Delivered February, 1928.)

INTRODUCTORY.

The phenomena exhibited by metals when subjected to repeated cycles of stress has, by common usage, become associated with the title of "Fatigue"; the term is not ideal, being indefinite and often misleading. It is extremely

difficult, however, to find a substitute without unduly restricting the scope of this most important subject, and hence, for the purposes of these lectures, the "Fatigue of Metals" is defined as the behaviour of metals under repeated cycles of stress.

In view of the complexity of the subject it is apparent that the method of treatment adopted in three lectures must be selective rather than comprehensive, yet, as fatigue has not, to my knowledge, been previously dealt with in Cantor Lectures, some attempt at a general survey must also be made. I have endeavoured to effect a compromise by devoting detailed attention to those very latest developments of fatigue—such as the effects of high frequency, of elevated temperatures, of contact substance and the behaviour of single metallic crystals—which aspects have not before been adequately surveyed, and are probably not generally known, while also discussing, in a less detailed manner, some of the better known fatigue phenomena. (A balanced and detailed general treatment of the subject will be found elsewhere¹, while the results of many thousands of actual fatigue tests have been tabulated in Vol. 2 of the International Critical Tables² and will be of service to those requiring comprehensive fatigue data relating to a very great number of metals and alloys in a variety of conditions of manufacture and heat treatment).

EARLY HISTORY.

Even a century ago, the strength of structural materials was estimated from tests on small specimens, and of these tests, the tensile test was regarded as the most valuable. As testing appliances improved, attention was paid to the limit of proportionality and/or yield point. The underlying principle of design appeared to be based on a belief that if working stresses were restricted within the limit of proportionality, deformation would not occur, while the reserve of strength between the limit of proportionality and the ultimate tensile strength was an insurance against fracture when overloads due to unknown contingencies were applied.

In 1837, and again in 1843, Hodgkinson reported to the British Association that his experiments on transversely-loaded bars of cast iron had shewn that "the maxim of loading bodies within the elastic limit has no foundation in nature; that there is no weight, however small, that will not produce a set and permanent change in a body, and that bodies when bent have the arrangement of their particles altered to the centre; and when bodies, as the axles of railway carriages, are alternately bent, first one way and then the opposite, at every revolution, we may expect that a total change in the arrangement of their particles will ensue."

In 1848, James Thomson, without abandoning the idea of a state of primitive

1. "The Fatigue of Metals." By H. J. Gough. Ernest Benn & Co. London, 1924.

2. See Section "Fatigue of Metals." By H. J. Gough.

elasticity, showed that the initial limits of proportionality of materials might be very low, due to the existence of internal stresses and strains induced in the process of manufacture. Following the application of a heavy load, however, these stresses would be relieved by the process of plastic yielding, and subsequent applications of smaller loads would not be accompanied by further permanent sets or alteration of form. James Thomson enunciated the following fundamental theorem:—"There are two elastic limits for any material, between which the displacements or deflexions, or what may in general be termed changes of form, must be confined, if we wish to avoid giving the material a set, or in the case of variable strains, if we wish to avoid giving it a succession of sets which would bring about its destruction; . . . these limits may, therefore, with propriety, be called the superior and inferior limit of the change of form of the material for the particular arrangement which has been given to its particles; that these limits are not fixed for any given material, but that if the change of form be continued beyond either limit, two new limits will, by means of an alteration in the arrangement of the particles of the material, be given to it in place of those which it previously possessed."

A Royal Commission was appointed in 1849 to inquire into the application of iron to railway structures and a series of experiments were made by James and Galton with a view to ascertaining the effect of repeated changes of load on iron. One of the important conclusions reached was that cast iron could be fractured under repetitions of a load of a magnitude insufficient to produce fracture on a single application, but that this was not due to a deterioration of static strength with time, for the static strength was unaltered. The effect of repeated stresses on iron received no further attention until 1860-61, when Sir William Fairbairn carried out his famous tests for the Board of Trade on a built-up wrought iron girder. This girder which was 22 feet long and 16 inches deep, had an estimated breaking strength of 12 tons. By means of a crank driven by belting, a given load was applied (with impact) to and removed from the mid-section of the girder. Repetition tests were made with each of a number of loads which varied from 3 tons to 4.7 tons. The experiments shewed that a girder was apparently able to bear a very great number of applications (over three millions) of a load of three tons at the centre, producing a stress of 5.7 tons per sq. inch in the tension flange, without any signs of failure or of decreasing strength, but that greater loads caused fracture at a smaller number of applications. Fairbairn concluded from these experiments that there was a limiting load which could be applied for an indefinitely great number of times. This conclusion when considered in view of the early period at which it was made, stands out as one of the great sign-posts in the history of fatigue. Fairbairn's apparatus is of added interest, as it represents one of the very few tests which have ever been made on a full-sized built-up structural component.

The year 1870 saw the publication of the results of Wohler's famous experi-

ments. Special machines* were designed for repeated loading tests employing direct, bending and torsional stresses. The materials used were wrought iron and steel as used for plates, axles, etc. The type of testing machine in which the specimen is in the form of a rotating beam has become associated with Wohler's name, and it can safely be said that over 90% of the experimental researches in fatigue that have been conducted have been made on machines of this type. Wohler's tests included investigations into the relative effects of the *range* of stress and the *maximum stress* of the cycle, the effects of various types of stress (direct, bending and torsional) and the effect of sudden changes of section of the specimen. The results, in addition to confirming Fairbairn's conclusions, brought out the very important new fact that the value of the range of applied stress was a much more important factor on the life of the specimen than the actual maximum or minimum stress of the cycle, although the safe range diminished as the maximum stress increased. The importance of avoiding sudden changes of section in parts subjected to fatigue stresses was also clearly demonstrated. The working speed of Wohler's machines was certainly less than 100 cycles of stress per minute, and some idea of the magnitude of the research will be obtained when it is remembered that many of Wohler's specimens were subjected to as many as 50 millions of cycles, while one specimen of axle iron was submitted to over 132 millions of reversals of bending stress (± 7.6 tons per sq. inch); it remained unbroken.

Wohler's work in Germany was continued and its results confirmed by Spangenburg (1874-75), and Bauschinger (1881 and succeeding years). The most important of Bauschinger's experiments relate to a classical study of the effect of repeated stresses and of rest and heat treatment upon the elasticity of metals. Bauschinger's work is too detailed to be summarised here. Briefly, it may be said to have established on a firm experimental basis the theorem of James Thomson previously referred to. Bauschinger's results may be interpreted as demonstrating that the range of stress which a material will withstand for a very great number of applications is substantially an elastic range; the elastic limits—called the "natural" elastic limits—corresponding to the maximum and minimum stresses of the range are conferred by the applied stresses; they usually bear no relation to the "primitive" elastic limits possessed by the metal in the unstressed state.

This brief early historical survey of the subject may be appropriately concluded with a reference to the work of Baker (published in 1886), who undertook a series of fatigue experiments in connection with the construction of the Forth Bridge, the special object being to compare the relative merits of the steel used in the bridge as compared with hard steel and with iron. The tests included Wohler tests, plane bending tests, direct stress tests and tests on full-size riveted girders. Apart from the design data perhaps the most noteworthy

3. For details of these machines see Unwin's "Testing of Materials of Construction," pp.367/369; see also Gough's "Fatigue of Metals," pp.13/38, for diagrammatic sketches.

result was the observed fact that the cause of failure under repeated stresses is "very frequently not so much a gradual deterioration or crystallisation of the metal as the establishment of small but growing flaws."

Thus, the stimulus to the study of the subject in the early days was undoubtedly due to the replacement of masonry and brickwork bridges by wrought iron structures and to the evolution and development of the steam locomotive; the investigations were mainly of a purely experimental character rendered necessary by engineering requirements. This has equally applied even to the present day. The rapid improvement of steam reciprocating engines, the invention of the steam turbine, and the wonderfully rapid development of the motor car chiefly due to the possibilities of the internal combustion engine, all these achievements have resulted in the growing recognition of the importance of the fatigue-resisting properties of materials. Finally, the imperious demands, for aircraft purposes, for prime movers of great power but of the minimum weight, makes a knowledge and due appreciation of fatigue phenomena an absolute essential for the purpose of engineering design.

SECTION I.

FATIGUE STRENGTH OF METALS RELATED TO THE EXTERNAL STRAINING FORCES (STRESS EFFECTS).

In this Section—unless otherwise stated—it will be considered that the applied stresses vary cyclically between maximum and minimum values and without shock; also that the variation of stress on either side of the mean or average stress of the cycle is, at least approximately, simple harmonic; also, that the specimen is tested under the ordinary atmospheric conditions. Any such cycle is most conveniently expressed as $M \pm R/2$, where M is the average stress and R is the algebraic difference between the maximum and minimum stresses of the cycle. Such stress cycles are conveniently classified into three types:—(i) *Alternating*, where the maximum and minimum stresses are of opposite sign; (ii) *Repeated*, where the minimum stress has zero value, and (iii) *Fluctuating or Pulsating*, where the maximum and minimum stresses are of the same sign. The special case of alternating stress in which the mean stress has zero value will be referred to as *reversed* stress. Then, if the frequency, or reciprocal of the period, of the cycle is also stated, the cycle is completely defined.

1. STRESS SYSTEMS EMPLOYED IN THE LABORATORY AND SOME TYPICAL TESTING MACHINES.

Fatigue testing has developed three main types of machines for applying, respectively, cycles of direct, bending and torsional stresses. As typical modern machines of the first type may be mentioned those due to Reynolds

and Smith⁴, also Stanton⁵—both employing inertia forces—and Haigh⁶ (electromagnetic). The Haigh Machine is made on a commercial basis and is used extensively in many research laboratories. The majority of fatigue testing, however, has been carried out on machines based on Wohler's rotating bar machine for applying cycles of reversed bending stresses. In its simplest—and original—form, the specimen is a rotating cantilever with a single end load. The maximum range of stress in the specimen is usually confined to one section only. Various alternative forms have been adopted to overcome this. McAdam⁷ uses a tapered test piece in which the calculated stresses are constant over a definite length. In other machines by employing two loads⁸, ⁹(three or four point loading) a constant bending moment (without shear) is applied to a required length of the specimen. These various forms of Wohler machine have been studied for many years at the National Physical Laboratory, and we find that, provided care is taken to avoid too rapid changes of section, the test results obtained from all types are equally satisfactory. H. F. Moore¹⁰ uses a form of Wohler Machine in which one end of the specimen is fixed; by means of a spring (co-axial with the specimen) a static tensile stress can be superimposed on the reversed bending stresses. Other machines apply plane-bending stresses; the Upton-Lewis machine¹¹ is of the spring loaded type, while three other types have recently been developed at the National Physical Laboratory¹². Typical machines for applying torsional stresses are those due to Olsen-Foster¹³, Stromeyer¹⁴ and Hankins.¹⁵

2. THE PROBLEM OF THE EXISTENCE OF A SAFE RANGE OF STRESS FOR AN INDEFINITELY GREATER NUMBER OF CYCLES OF STRESS.

We have seen that the work of the early investigators shewed clearly that metals fracture under repeated applications of a stress less than that stress required to produce failure on the first application; further, that as the range of stress decreases, the number of repetitions required to produce failure increases. Thus a certain range of stress, applied to a given material, becomes associated with a given "life" or "endurance"; provided no "speed effect" exists, this life or endurance is a matter of number of reversals only and not of time. The engineering problem, therefore, resolves itself into an enquiry

4. Phil. Trans. Roy. Soc. Vol. 199. 1902.

5. Engineering, February 17th, 1905.

6. Jour. Inst. Metals, 2, Vol. 18, 1917.

7. Proc. Amer. Soc. Test. Mat., Vol. 16, Pt. 2, 1916.

8. Gough, "Fatigue of Metals," London, 1924.

9. R. R. Moore, Proc. Amer. Soc. Test. Mat., Vol. Pt. 2, 1927.

10. Bulletin No. 152, Eng. Expt. Stat. Univ. Ill. Urbana.

11. Amer. Mach. October 17th & 24th., 1922.

12. See: Annual Reports, National Physical Laboratory, 1920 onwards, H.M. Stationery Office, London.

13. Bulletin No. 124, Eng. Expt. Station, Univ. Ill. Urbana.

14. Proc. Roy. Soc. Vol. 90. 1914.

15. Engineering, June 25th, 1926.

as to whether the range of stress continues to diminish with increased endurance according to a regular law which holds even down to zero stress, and, if this is found to be the case, to establish the nature of the law. Fairbairn, chiefly interested in bridge structures, was satisfied that his wrought iron girders would withstand a satisfactory working range of stress for 12 million reversals, which he considered was equivalent to a period of 328 years, and thus exceeding the life of the bridge. Wohler, concerned primarily with locomotive practice, apparently considered necessary endurances of a higher order and usually carried out his tests on a 30/50 millions reversals basis. In the present days of high working speeds, machine and structural components are required to withstand thousands of millions of cycles of stress, and as it is impracticable to carry out ordinary laboratory tests at these lengths, circumstantial evidence must be considered.

Let us discuss the results of a typical series of laboratory endurance tests. From the great choice available, I have chosen one of Wohler's tests, as a lecture on Fatigue cannot be too full of references to the work of that great investigator. Table I gives the results of his reversed bending tests (rotating bar) on an axle iron.

TABLE I.
WOHLER'S TESTS ON AXLE IRON (PHOENIX COMPANY).

Specimen No.	Applied Range of Stress (tons per sq. inch).	Endurance (Number of repetitions to fracture).
1	± 15.3	56,430
2	± 14.3	99,000
3	± 13.4	183,145
4	± 12.4	479,490
5	± 11.5	909,840
6	± 10.5	3,632,588
7	± 9.6	4,917,992
8	± 8.6	19,186,791
9	± 7.6	132,250,000 (unbroken)

In Fig. 1 (a) these data have been plotted, stress (S) against number of reversals to fracture (N); such a curve is usually referred to as an S/N curve. It is apparent that the form of the most important part of the curve (20 to 130×10^6 reversals) can be estimated variously. It can be made asymptotic to a horizontal line representing a range of, say, ± 7.7 tons per sq. inch, and the deduction drawn that the material can withstand this range of stress indefinitely. If, on the other hand, a straight line be drawn through the points 8 and 9, and it be assumed that this slope is afterwards maintained, then it may be estimated that the safe range of stress after a thousand millions

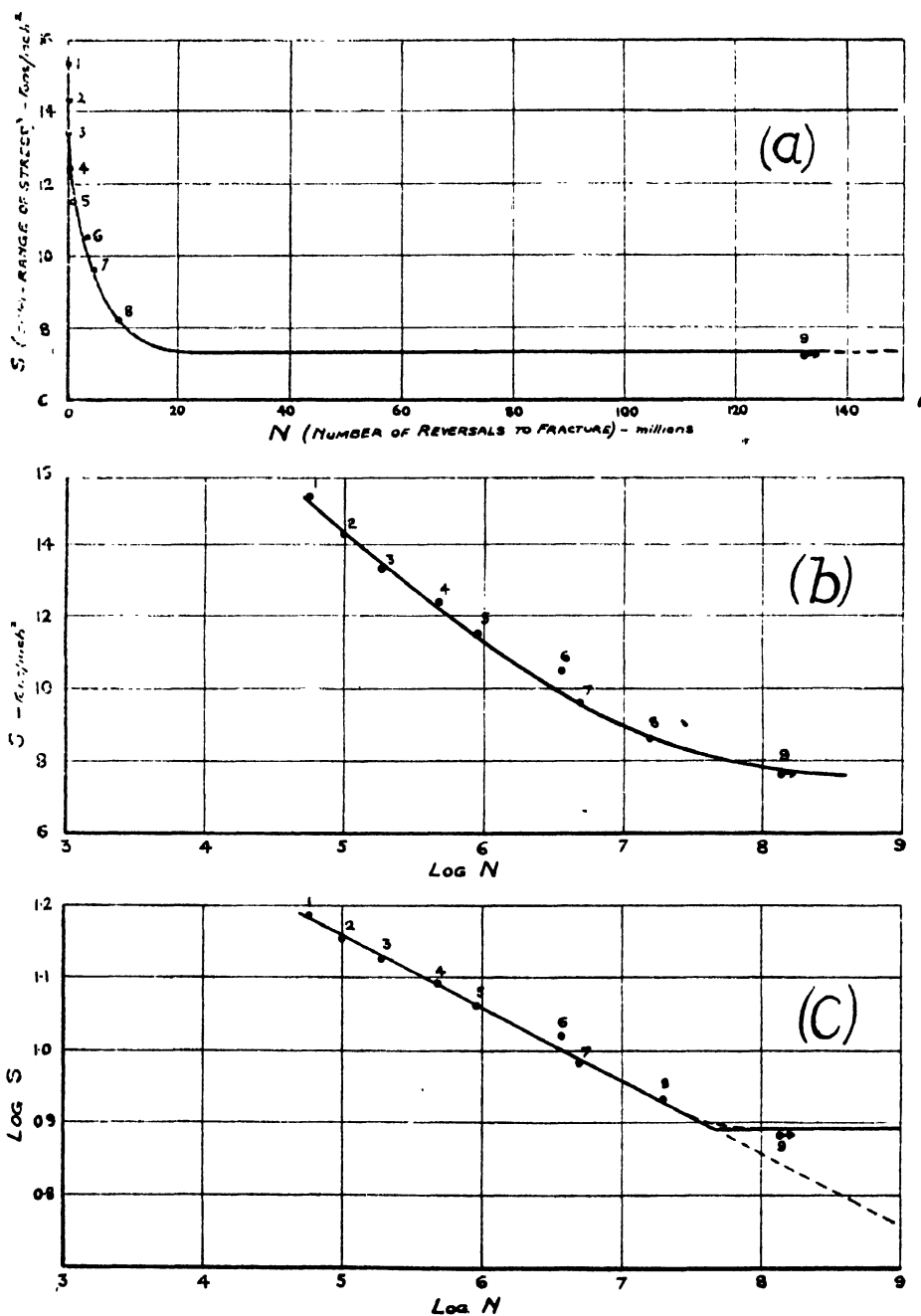


FIG. 1—Wöhler's Tests on Axle Iron.

of cycles has been reduced to *zero* value, with all the implications that that conclusion entails. In Fig. 1 (b) semi-ranges of stress (ordinary scale) have been plotted against endurance (logarithmic scale). In a "semi-log" plot of this sort, widely varying endurances can be expressed with the same degree of percentage accuracy. A much smoother curve is obtained suggesting an approach to a horizontal asymptote. The errors involved in estimating this asymptotic value are still dangerously wide. In Fig. 1 (c) $\log S$ is plotted against $\log N$. It will be seen that the points 1-8 fall, with fair precision, on a straight line, but result No. 9 departs widely from this line, indicating that, somewhere between 10^7 and 10^8 reversals, a discontinuity occurs in the curve. Wohler's tests did not provide sufficient data of these particular endurances, to reveal completely this discontinuity, but the test suggests clearly the nature of the circumstantial evidence on which rests the present accepted belief in the existence of a definite limiting range of stress for many metals.

In 1910, Basquin¹⁶ analysed a large number of fatigue data and shewed that if these data were plotted logarithmically ($\log S/\log N$) the experimental points, corresponding to tests on any individual metal, fell on a straight line. This applied to endurances extending to 10^6 or 10^7 reversals; at this point, however, a sudden discontinuity occurred, and the subsequent $\log S/\log N$ curve appeared to be a straight line parallel to the N axis. Basquin's work was responsible for a large number of very lengthy endurance tests that have since been made on a wide range of metals by a number of investigators. As a result, it is now established that for the majority of metals and alloys in common use, the S/N curve *does* become horizontal and continues to remain horizontal within the limits of investigation. As there appears to be no reason why, at some stage, the curve should again change its inclination, the important conclusion is now generally accepted that for *most* metals and metallic alloys there does exist a definite limiting range of stress for which there is sufficiently strong evidence (although of a circumstantial nature) to suggest that the metal can withstand an indefinitely great number of repetitions without fracture. This range is variously known as (a) the fatigue range, (b) the limiting range of stress, or (c) the endurance range. It has become usual, however, to express this value in terms of the semi-range¹⁷ which is then referred to as the fatigue limit, limiting stress or endurance limit. Where it is desired to express the range of stress or stress (x) which is safe for a given number of reversals (N), although the S/N curve *may* not have become horizontal at that number of reversals, use is made of the expression "Endurance Limit (N) = $\pm x$ tons per sq. inch."

The endurance at which the S/N curve becomes horizontal is of very great importance from an engineering point of view, as it determines the length

16. Proc. Amer. Soc. Test. Mat., Vol. X., 1910.

17. This method of expression has undoubtedly arisen from the general practice of employing Wohler machines for fatigue tests in which cycles of reversed bending stresses are applied, the mean stress of the cycle being zero.

TABLE 2.

TYPICAL LENGTHY ENDURANCE TEST DATA OBTAINED WITH WOHLER (ROTATING-BAR) MACHINES.

N denotes reversals basis on which tests were made.

* denotes endurance at which the logS/logN curve becomes, and remains, horizontal.

General Description.		Metals.	Ultimate Tensile Strength (Tons per sq. inch). T.S.	Endurance Limit (Tons per sq. inch). E.L.	N Mil-lions.	n Mil-lions.	Ratio. E.L. T.S.	
Ferrous Metals—Plain Carbon and Alloy Steels.	Wrought.	Ingot Iron. 0.02% C. ...	18.9	11.6	100	4	0.61	
		Wrought Iron. 0.045% C. ...	20.9	10.3	100	11	0.49	
		CARBON STEELS. 0.13% C....	31.6	16.7	250	0.6	0.53	
		0.20% C....	{	25.8	11.2	100	10	0.43
				25.3	12.9	100	1	0.51
				38.8	18.3	100	3	0.47
				37.3	17.4	250	6	0.47
				32.1	14.7	100	6	0.46
			{	50.0	25.5	100	3	0.51
				34.3	14.3	100	3	0.42
				38.2	16.5	100	2	0.43
				43.3	21.4	100	0.5	0.49
				47.7	25.4	100	1	0.53
		0.49% C....	{	54.4	28.6	100	0.5	0.53
				56.6	31.4	100	1	0.54
				39.7	17.4	100	0.6	0.44
				42.6	23.7	100	1	0.56
				49.4	26.3	100	1	0.53
		0.53% C....	{	57.9	29.0	100	0.7	0.50
				57.9	30.4	100	1	0.51
				50.0	20.5	100	5	0.41
				37.6	13.6	100	2	0.36
				51.4	25.0	100	1	0.49
		0.93% C....	{	84.0	43.7	100	1	0.52
				52.2	22.3	100	1	0.43
				61.9	30.4	100	1	0.49
				80.4	41.1	100	1	0.51
	98.4			46.9	100	0.3	0.48	
	1.20% C....	{	100.5	48.3	100	0.4	0.48	
	ALLOY STEELS.							
	13% Cr. Steel. 0.19% C. ...	{	50.2	21.4	100	2	0.43	
		{	45.4	24.1	100	3	0.53	
	{	55.1	28.6	100	3	0.52		
3½% Nickel Steel. 0.4% C.	{	77.1	39.8	100	2	0.52		
	{	126.0	50.0	100	1	0.40		
	{	131.5	53.6	100	1	0.41		
Nickel-Chromium Steel.	{	39	21.9	100	3	0.56		
3.33% Ni. 0.87% Cr.	{							
0.24% C.		61.9	30.4	100	1	0.49		
Vanadium Steel.		45.4	23.2	100	1	0.51		
0.16% V. 0.57% C.	{	48.0	25.4	100	1	0.53		
Cast.	Cast.	CAST IRONS.						
		Graphitic Carbon. Combined Silicon.						
		2.72% 0.84% 1.42%	11.7	5.4	100	2	0.46	
		2.78% 0.57% 1.10%	11.3	4.0	100	5	0.35	
		3.25% 0.05% 0.14%	9.6	3.1	100	5	0.32	
		CAST STEELS.						
		0.35% C. 1.71% Mn. 0.30% Si.	{	36.1	14.3		1	0.40
		(As received; also various heat treatments).		to	to	100	to	to
				48.6	21.4		10	0.45
		0.25% C. 0.68% Mn. 0.32% Si.		30.0	12.1		2	0.40
		(As received; also various heat treatments).		to	to	100	to	to
			{	34.4	15.6		12	0.46

TABLE 2—CONTINUED.

TYPICAL LENGTHY ENDURANCE TEST DATA OBTAINED WITH WOHLER (ROTATING-BAR) MACHINES.

N denotes reversals basis on which tests were made.
n denotes endurance at which the logS/logN curve becomes, and remains, horizontal.

General Description.	Metals.	Ultimate Tensile Strength (Tons per sq. inch). T.S.	Endurance Limit (Tons per sq. inch). E.L.	N Mil-lions.	n Mil-lions.	Ratio : E.L. T.S.
Light Non-Ferrous Alloys	Aluminium ...	10.1	4.7	100	6	0.46
	Duralumin. { Rolled... ...	22.8	6.2	400	>400	0.27
	{ Annealed ...	11.2	4.5	200	>200	0.40
	{ Tempered ...	22.9	5.4	400	4½	0.24
	Magnesium. Extruded ...	14.5	3.6	200	2	0.25
	Magnesium Alloys.					
	4% Al. ...	15.7	5.4	600	½	0.34
	4% Al. 0.25% Mn. ...	17.4	6.7	100	1	0.38
	6.5% Al. ...	18.4	5.8	600	½	0.31
	6.5% Al. 0.25% Mn. ...	19.8	6.8	100	½	0.34
Heavy Non-Ferrous Alloys.	10% Cu. ...	17.4	5.4	600	½	0.31
	Electron Metal ...	16.3	7.6	200	30	0.47
	Copper. { Annealed ...	14.5	4.5	500	20	0.31
	{ Cold-drawn ...	25.1	4.5	500	>500	0.18
	60/40 Brass. { Annealed... ...	29.5	12.9	500	>500	0.44
	{ Cold-drawn ...	43.3	11.6	500	50	0.27
	Naval Brass ...	30.5	9.8	300	10	0.32
	10% Aluminium { As Cast ...	26.4	10.3	60	3	0.39
	{ Heat treated ...	34.7	12.1	40	1	0.35
	Bronze. { Annealed ...	20.4	10.3	1000	10	0.50
	(5% Sn.) { Cold-drawn ...	38.0	12.1	500	50	0.32
	Manganese Bronze. Cast ...	31.3	7.6	150	20	0.24
	Nickel, Annealed ...	31.2	12.5	100	50	0.40
	Monel Metal, Hot-rolled ...	40.1	14.3	450	>450	0.36

The typical results given in Table 2 are conveniently discussed under two sections relating to ferrous and non-ferrous metals respectively.

of test necessary to disclose experimentally the fatigue limit of a material¹. In Table 2 will be found a few typical data relating to a wide range of metals tested in Wohler Machines employing reversed bending stresses. Solid round specimens of small diameters (¼-in. to ½-in.) were used throughout. In selecting data for this Table I have, necessarily, been restricted to results of tests where very lengthy endurances have been investigated and of which details of the complete S/N curves have been given. A few tests from the National Physical Laboratory are included, but the majority of the data is due to H. F. Moore (and his colleagues), to R. R. Moore, and to McAdam. These investigators have carried out a very great number of lengthy endurance tests on a very wide range of metals. Complete details of composition and heat treatment have been summarised elsewhere.¹⁸

18. International Critical Tables. Vol. 2, pp. 595/608.

FERROUS METALS.

Without exception, the $\log S/\log N$ curves become horizontal in the neighbourhood of 10^7 reversals, and remain so within the limit investigated (10^6 - 10^8 reversals). From this it may be deduced (1) that ferrous metals possess a real fatigue range for an indefinitely great number of cycles of stress, and (2) that, from the commercial point of view, laboratory fatigue testing on a 10^7 reversals basis is sufficient to determine the value of this range. Attention is also drawn to the values of the ratio given in the last column of the Table. With the exception of one high value of 0.61 and one low value of 0.36, all other values are restricted to the limits of 0.40 to 0.55, irrespective of the actual composition, heat treatment, tensile strength or endurance limit of the metal in question. The constancy of this ratio—which remains to be explained—is extremely valuable in laboratory testing, as, with some experience, it is possible to estimate the endurance limit (for reversed bending tests) very closely indeed, and thus save a waste of specimens. It is not necessary to determine the tensile strength for this purpose, as the relation of the Brinell Hardness Number to the tensile strength of steels is a fairly constant value. Hence, a Brinell test made on the end of a specimen of steel is a satisfactory means of estimating very approximately the fatigue range of the material. This practice, together with the employment of a 10^7 reversals basis for fatigue testing—based on the result of 18 years' experience—has been used for many years at the National Physical Laboratory and has been found to be very satisfactory.

NON-FERROUS METALS.

In the case of four metals—certain batches of duralumin, copper, brass and monel metal—the $\log S/\log N$ curves shew no approach to a horizontal form at the maximum endurances investigated (200 – 400×10^6 cycles). The remaining metals develop a limiting stress at endurances varying from less than 10^6 reversals up to 50×10^6 reversals. These two characteristics mark a definite difference between ferrous and non-ferrous metals in general. On the theoretical side we conclude that for many non-ferrous metals, the existence of a definite limiting range of stress has been established; for certain materials, however, greater endurances must be investigated. From the testing point of view, it is clear that fatigue tests on, at least, a 50×10^6 reversals basis are necessary with certain non-ferrous metals to obtain reliable results.

The value of the ratio $\frac{E.L.}{T.S.}$ for non-ferrous metals is seen to vary very

widely, much more so than for steels and, on the average, is much lower. As a means of estimating the endurance limit, the tensile strength alone has very limited value and this applies equally to the Brinell Hardness Number.

FATIGUE STRENGTH UNDER DIRECT AND TORSIONAL STRESSES.

The tests previously discussed all refer to cycles of reversed bending stresses. The same general conclusions apply equally to metals subjected to cycles of direct and torsional stresses, although very few lengthy endurance tests have been carried out.* The experience of the National Physical Laboratory may be summarised as follows :—

1. Under cycles of reversed direct stresses, the limiting range of stress is developed at a smaller number of cycles than under bending or torsional stresses.

2. Hollow specimens develop the endurance limit at a smaller number of reversals than solid specimens in the case of bending or torsional stresses.

3. As the mean stress of the cycle increases from zero, the required number of cycles to disclose the endurance limit, decreases; this applies to direct, bending, and torsional stresses.

4.¹⁹ The value of the endurance limit under reversed bending stresses generally exceeds that for reversed direct stresses by an amount that varies from 0 to a maximum (one case only) of 20%. The average difference, for ferrous metals, is about 8% and, in general, diminishes with increased hardness of the metal. The endurance limit under reversed torsional stresses (in terms of shear stress) varies between the values of 0.48 and 0.65 (with an average value of 0.56) of the reversed bending values.

3. THE EFFECT OF THE FREQUENCY OF THE APPLIED CYCLE OF STRESS UPON THE ENDURANCE LIMIT.

In laboratory fatigue tests the frequency of applied loading is often determined by the type of testing machine employed; a usual frequency is 2,000 cycles per minute, but may be as low as 100 or as high as 5,000. To effect comparisons between different test data, therefore, it is necessary to know if the endurance limit is dependent on the frequency of loading. The importance of the question to designers of high speed machinery needs no emphasis.

Some experiments²² made in 1902 indicated that the fatigue range of mild steel, also cast steel, diminished regularly with increased frequency of stress cycle, so that at a frequency of 2,000 cycles per minute the safe range was only 60% of that at 1,300 cycles per minute. In 1911 Hopkinson²³ drew attention to the importance of the question and carried out some fatigue tests on mild steel at a frequency of 7,000 cycles per minute. Comparative tests

*A number of tests, on a 10⁶ reversals basis, have been made by the writer at the N.P.L.

19. For a typical series of tests on these relations between the endurance limits and a theoretical discussion of the subject shewing that these differences are to be expected in ductile metals, see the following papers :—

20. Gough & Tapsell, No. 1012, Reports & Memoranda Series, April, 1926, Aero. Research Committee; (H.M. Stationery Office).

21. Griffiths, Report. Brit. Assoc. Sect. G., 1924.

22. Phil. Trans. Roy. Soc., Vol. 199, 1902.

23. Proc. Roy. Soc. A. Vol. 86, 1911.

were made on the same material by Stanton at the National Physical Laboratory on two types of machines. The fatigue ranges recorded were as follows:—

- (Stanton.) Reversed Direct Stresses at 1000/1300 cycles per min.
 $= \pm 12.5$ tons per sq. inch.
 (Hopkinson.) Reversed Direct Stresses at 7,000 cycles per min.
 $= \pm 14.5$ tons per sq. inch.
 (Stanton.) Reversed Bending Stresses at 2,200 cycles per minute.
 $= \pm 13.0$ tons per sq. inch.

These results indicated that the increased speed had not reduced the fatigue range, but as tests had not been made on any one machine at more than one speed, the existence of a speed effect was not shewn conclusively.

The problem has since been attacked by a number of investigators (Eden, Rose and Cunningham,²⁴ Haigh,²⁵ Hankins,²⁶ Gough,²⁷ Kommers,²⁸ Roos,²⁹ Stanton and Pannell,³⁰ Moore and Jasper³¹). As a result it has now been definitely established that the fatigue range under reversed bending stresses is not affected by cycle frequencies between 150 and 5,000 cycles per minute, and, in the case of direct stresses, frequencies of 2,000 up to 6,000 cycles per minute give the same result. Jenkin³² has recently investigated the effect of much higher frequencies up to 120,000 cycles per minute. The specimen is supported at each end and is maintained, electrically, in a state of resonance at its natural frequency. The poles of an electro-magnet surround the mid-section of the specimen along which alternating current passes. By adjusting the frequency of the current to be exactly equal to the natural frequency of the test piece, the vibrations are maintained with a very small expenditure of power. By regulating the current, the amplitude of the vibration can be adjusted to any desired magnitude. The length of the test piece is varied to suit the actual frequency required, and the amplitude of the vibration in any test is determined by using a measuring microscope. Three materials were tested—copper, Armco Iron and mild Steel; the deduced endurance limits (12 to 16 x 10⁶ reversals basis) as calculated from the observed ranges of strain and the experimentally determined values of E (Young's Modulus) are summarised in Table 3.

The "fatigue limit-periodic time" curves for each of the three metals investigated reveal a rapid increase in slope at high frequencies. The curves appear to be approaching horizontal asymptotes at some frequency about 3,000 cycles per minute and the results of the previous experiments at still

24. Proc. Inst. Mec. Engrs., 1911.

25. Journ. Inst. Met. 2, Vol. 18., 1917.

26. No. 789, Repts. & Mem. Ser. Aero. Res. Ctee, Nov., 1921.

27. Proc. Roy. Soc. A. Vol. 104, 1923.

28. See "Materials of Construction," Johnson, 5th Ed. Ch. 28.

29. Proc. Inter. Assoc. Test. Mat., Paper V. 2B., 1912.

30. Proc. Inst. Civ. Engrs. Vol. 188, 1911-12.

31. Bulletins, Univ. Illinois. Nos. 124, 136 & 142.

32. Proc. Roy. Soc. A. Vol. 109, 1925.

lower frequencies shew that the curves attain and continue along these horizontal asymptotes.

TABLE 3.
RESULTS OF HIGH FREQUENCY FATIGUE TESTS (JENKIN).

MATERIAL.					
MILD STEEL.		ARMCO IRON.		COPPER.	
Frequency.	Endurance Limit (Tons per sq. inch).	Frequency.	Endurance Limit (Tons per sq. inch).	Frequency.	Endurance Limit (Tons per sq. inch).
3,000	± 16.3	3,000	± 15.75	3,000	± 4.88
30,000	± 16.85	30,000	± 16.65	30,000	± 5.01
60,000	± 17.35	60,000	± 16.98	60,000	± 5.33
				120,000	± 5.53

Thus the present position with regard to the effect of frequency upon the fatigue limit is that no appreciable speed effect exists up to frequencies of about 7,000 cycles per minute (at air temperatures). With higher frequencies, the fatigue strength increases with frequency at an increasing rate up to the highest frequencies investigated (120,000 cycles per minute).³³

I must stress the fact that these conclusions must be confined to tests made at air temperature. We shall see later that it is very probable that at elevated temperatures a marked speed effect is operative at frequencies as low as 1,000 cycles per minute. This suggests that with increased temperature, the fatigue limit-periodic time curves are displaced bodily to the right, along the periodic time axis and, although we have at present no experimental evidence of this, such a result would not be unexpected.

4. THE INFLUENCE OF THE MEAN STRESS OF THE CYCLE ON THE LIMITING RANGE OF STRESS.

Again denoting any repeated cycle of stress by $M \pm \frac{R}{2}$, where M and R refer to the mean stress and range of stress respectively, it is now important to determine if any quantitative relation can be established between these variables for the special case when R is the endurance limit, fatigue range, or limiting range of stress. The work of Wohler and Bauschinger disclosed the fact that the limiting range of stress of a material is not a constant quantity

33. Professor Jenkin also designed an apparatus for applying reversed torsional strains at frequencies up to 300,000 cycles per minute. In tests made on copper at frequencies of 240,000 and 180,000 cycles per minute, it was found impossible to fracture the specimens, the apparatus not being sufficiently powerful to supply energy in excess of that absorbed by the test piece (due to hysteresis) as the fatigue limit was approached. By using an entirely new type of apparatus, Professor Jenkin has, more recently, successfully investigated the characteristics of metals exhibited at these extremely high frequencies; the results of the research are awaited with great interest.

but is dependent, to some extent, on the mean or average stress which must therefore be specified when the fatigue-resisting properties of the metal are quoted.

Gerber analysed the experimental results obtained by Wohler and Bauschinger and found that if the safe ranges of stress were plotted as ordinates, and the minimum stress of the cycle as abscissae, the experimental data fell approximately on a parabolic curve. His original equation can be re-written in the very convenient form

$$R = R_r \left\{ 1 - \left(\frac{M}{f} \right)^2 \right\} \dots\dots\dots(1)$$

where R = Limiting Range of Stress, of which M is the Mean Stress.

R_r = Limiting Range of Stress for reversed stresses ($M = 0$).

f = Statical Ultimate Strength of the material.

Thus, according to this relation, as M increases from zero value to that of the statical ultimate strength, the safe range diminishes (according to a parabolic relation) to zero value. This relation is usually referred to as the "Gerber parabola."

Goodman has suggested a relation based on an entirely different principle. He assumed that the destructive effect of a repeated cycle of stress was that of a "live load," and that, therefore, the safe range of stress was reached when the algebraic sum of the minimum stress of the cycle and twice the range of stress became equal to the statical breaking strength of the material. This demands that the limiting ranges for reversed stress, (R_r), for all metals, shall have the constant value of two-thirds of their ultimate strengths (f), and that the safe range (R) shall diminish, according to a *linear* relation, as the value of the mean stress (M) increases. When M equals f , R has zero value. Now the basis on which this law is founded is a fallacy (as in modern testing machines the method of applying the loading is such that there is no "live-load" effect) and, moreover, the constant value of $\frac{2}{3}$ for the ratio $\frac{\text{Limiting Range}}{\text{Ultimate Strength}}$

is *not* obtained. Nevertheless, with some metals, it is found that a *linear* relation obtains between M & R . Such a relation can be most conveniently expressed in the form

$$R = R_r \left(1 - \frac{M}{f} \right) \dots\dots\dots(2)$$

To distinguish between this general linear relation and the very special linear relation of Goodman, I have used the term "Modified Goodman" relation to denote the general case, but it must not be forgotten that the modification required effectually disproves the truth of the original assumption of "live" loading on which the Goodman law was founded. Both the Gerber and the "Modified Goodman" relations can be expressed in the same general form

$$R = R_r \left\{ 1 - \left(\frac{M}{f} \right)^x \right\} \dots\dots\dots(3)$$

TABLE 4.

TYPICAL EXPERIMENTAL DATA SHOWING THE VALUES OF THE LIMITING RANGE OF STRESS WITH VARIOUS MEAN STRESSES.

Applied Stress System.	Material.	* Ref. No.	STRESSES (Tons per sq. inch).			Investigator.
			Ultimate Tensile Strength.	Fatigue Tests.		
				Mean Stress of Cycle.	Safe Range of Stress.	
Direct Stresses Tension and Compression).	Bessemer Steel.	1	28.6	0 7.85 18.6	17.1 15.7 9.1	Bauschinger ³⁵
	0.13% Carbon Steel.	2	25.2	—12.2 — 9.35 — 5.2 0 4.95 9.87 12.80	19.5 21.5 23.5 26.0 24.5 21.5 17.5	Haigh. ³⁶
	Nickel Chromium Steel.	3	51.4	— 10.0 0 15.1 18.0 20.0 25.0 34.2 42.1	53.5 46.0 33.5 32.5 25.0 18.5 14.5 8.3	Lea ³⁷
	Naval Brass.	4	28.7	— 6.0 — 3.26 0 4.0 6.23 7.72	29.0 27.4 24.0 21.0 19.2 17.5	Haigh ³⁸
	Plane Bending Stresses.	Spring Steel (H).	5	57.5	12.75 23.75 30.0 37.5	25.5 22.5 20.0 15.0
Reversed Bending Stresses with Super-imposed Tension or Compression.	3½% Nickel Steel H. & T.)	6	55.2	0 3.0 4.9 11.1 21.5 28.7 33.8	53.6 54.6 49.2 52.0 42.9 31.8 22.5	Moore and Jasper ³⁹
	0.53% Carbon Steel.	7	40.9	0 3.2 10.5 16.1 23.1	29.4 25.7 21.0 21.4 15.4	Moore and Jasper ³⁹
	Cast Iron.	8	14.1	3.46 0 — 5.71 —14.5	6.93 9.38 17.2 29.0	Moore, Lyon and Inglis ⁴⁰

*See Figure 2.

35. See "The Engineer," December 10th, 1886, Also January 7th, 1887.

36. Report British Association, 1915, p. 163.

37. No. 920. Reports & Mem. Ser. Aero. Res. Ctee., June, 1924.

38. Jour. Inst. Metals. 2. Vol. 18, 1917.

39. Bull. No. 136. Eng. Expt. Stat. Uni. Illinois, 1923.

40. Bull. No. 136. Eng. Expt. Stat. Uni. Illinois, 1923.

TABLE 4—CONTINUED.

TYPICAL EXPERIMENTAL DATA SHOWING THE VALUES OF THE LIMITING RANGE OF STRESS WITH VARIOUS MEAN STRESSES.

Applied Stress System.	Material.	* Ref. No.	STRESSES (Tons per sq. inch).			Investigator.
			Ultimate Tensile Strength.	Fatigue Tests.		
				Mean Stress of Cycle.	Safe Range of Stress.	
Torsional Stresses.	0.6% Carbon Steel (H. & T.).	9	78.5	0 24.0 40.0	47.0 44.0 31.0	Hankins ¹¹
	0.6% C. Steel (Normalised).	10	55.0	0 18.0 32.0	28.6 28.0 27.0	
	Chromium Vanadium Steel (H. & T.).	11	79.0	0 27.0 42.0	50.0 45.0 33.0	
	0.13% C. Steel (Normalised).	12	30.6	0 4 18.5	20.0 18.75 18.0	

where x has the values of 2 and 1 for the parabolic and linear relations respectively. By plotting the values of R and M expressed as fractions of the ultimate tensile strength of the metal, a diagram can be constructed in which the test data relating to a number of metals, of widely differing tensile strengths, can conveniently be compared in the simplest manner.

In Table 4 I have summarised the results of typical endurance tests. Experiments 1 to 4 were made on machines employing direct tensile and compressive stresses, No. 5 relates to plane bending, Nos. 6, 7 and 8 are some of the "tension-bending" tests carried out at Illinois, while Nos. 9 to 12 are torsion tests. (In this Table compressive stresses are denoted by the minus sign prefixed).

The results of Table 4 are plotted in Fig. 2, of which the right hand portion refers to tensile mean stresses. These curves will be discussed in detail.

(i) CYCLES OF DIRECT STRESSES.

The Bessemer steel (1) conforms accurately to the Gerber relation as expected. Mild Steel (2) conforms approximately to the same law, although at high mean stresses the safe range diminishes at a quicker rate than the parabolic relation demands; it is important to observe that the curve is symmetrical on both

* See Figure 2.

41. Bull. No. 164. Eng. Expt. Stat. Uni. Illinois, June, 1927.

sides of the zero mean stress line. Nickel chromium steel (3) and Naval Brass (4) conform to the modified Goodman relation and, in both cases, the safe range increases as the mean stress changes from tension to compression. (This experimental fact is supported by practical experience of the behaviour of connecting rods in aeroplane engines).

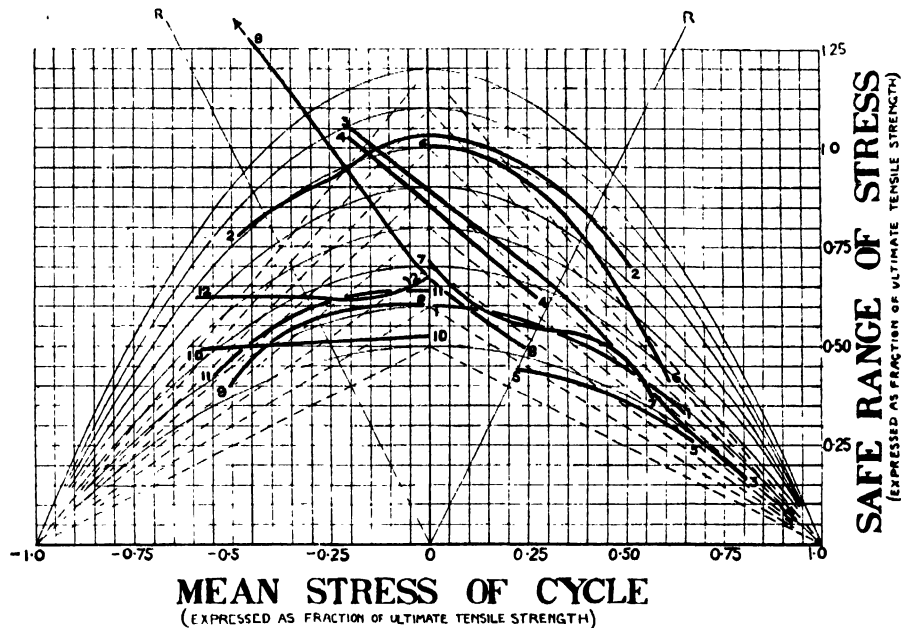


FIG. 2—Relations between the Limiting range of stress and the mean stress of the cycle.

(ii) BENDING STRESSES.

Wohler's tests on Spring Steel (5) subjected to *plane* bending stresses plot parabolically. The "tension-bending" test results plot in three different forms. The curve for nickel steel (6) lies intermediate between the parabolic and linear lines, the shape of the curve indicating that at still higher values of the mean stress the linear relation would predict unsafe ranges. The 0.53% carbon steel plots in an irregular manner, the *average* slope being not far removed from the modified Goodman line. The curve for cast iron (8) is extremely interesting. The ultimate compressive strength of this material being $3\frac{1}{2}$ times its tensile strength, it is not surprising to find that the safe range of stress increases greatly as the mean stress of the cycle becomes compressive. Turning to the torsion results, we see that with the normalised 0.65% carbon steel (10) and the mild steel (12), the safe range of stress is surprisingly constant over a wide range of mean stress.⁴² It should be remembered, however, that although the calculated *ranges* of stress are probably not greatly in error, yet,

⁴². See also, tests by McAdam, Proc. Amer. Soc. Test. Mat., 2, Vol. 24, 1924, who has reported similar experiments.

owing to plastic deformation, the *actual* stresses are almost certainly too high. With the spring steels (9) and (11)—in the hardened and tempered condition—the curves at first follow the parabolic relation while at higher values of mean stress the safe range is diminishing at a quicker rate than predicted by the Gerber law. The original publication should be consulted for the complete data for the cast iron (8) of Table 4.

GENERAL CONCLUSION.

There is no general relation for metals between the safe range of stress and the mean stress of the cycle. Some metals conform to the Gerber parabolic relation, others follow closely the modified Goodman linear relation, others conform to neither. In the absence of experimental data, a *safe not accurate* range of *alternating* stress can usually be estimated if the range for reversed stresses and the ultimate tensile stress are known by using the modified Goodman relation (cases where this would predict a slightly *unsafe* range of stress have been recorded,⁴³ but the error is usually of a small order). It is dangerous, however, to attempt to estimate the safe range of fluctuating stresses in this manner.

It is, perhaps, hardly necessary to point out that if the conditions of service of a machine or structural component do not permit of permanent deformation of the metal, the maximum stress of the cycle should not exceed the elastic limit of the material; the usual allowances (factor of safety) should also, of course, be made to allow for unknown contingencies and possible lack of homogeneity of the material.

GENERAL NOTE.

EXHIBITION OF THE SILVER PLATE OF THE OXFORD COLLEGES:—The above exhibition, inspired by the Worshipful Company of Goldsmiths of London and promoted by the Oxford Architectural and Historical Society, will be held in the Ashmolean Museum, Oxford, from 7th to 28th November, 1928, inclusive. It will consist of some three hundred pieces chosen from the College collections for their artistic and historic qualities, and will be remarkable if only as the first occasion that plate from all the Colleges has been exhibited together. It is the aim of the selectors to illustrate fully the artistic and technical resources of the silversmith's craft; and to set the achievements of the past as a stimulus alike to the public and to the designer of the present day, no less than as a criticism on both. The goldsmiths' workshops were, in the past, the schools of great sculptors, engravers and draughtsmen; and if the full possibilities of the craft are to be realised in the future, not only must the public once more become intelligent patrons of the designer, but the designer must seek new combinations of his technical equipment, using to the full all the resources of the modern workshop. A few well-known pieces of modern silverwork have been borrowed from outside the University by way of contrast, to illustrate the trend of the present-day movement. To assist this movement towards restoring something at least of its old vigour and opportunity to the art is part of the purpose of the exhibition.

43. See "Fatigue of Metals," Gough, pp. 77 to 79.

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PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

FATIGUE PHENOMENA, WITH SPECIAL REFERENCE TO SINGLE CRYSTALS.

By HERBERT JOHN GOUGH, M.B.E., D.Sc., Ph.D.

(Engineering Department, National Physical Laboratory, Teddington).

II.

(Delivered February, 1928).

SECTION II.

INFLUENCE OF SUDDEN CHANGES OF SECTION AND OF SURFACE DEFECTS UPON THE FATIGUE STRENGTH OF METALS.

In the preceding section we have seen that under laboratory conditions of test, a metal possesses a limiting fatigue resistance which is controlled principally by the nature of the metal itself and by the type of the applied stressing system. It is important to recognise that in such tests the specimens employed are of such a shape and with such carefully prepared surfaces that the maximum fatigue resisting properties are developed; when these results are applied to design such conditions may not be realised. For example, sudden changes of section as occurring in the junction of the shaft to the web in a crankshaft, of the tooth to the boss in a gear wheel,⁴⁴ of the presence of a screw thread in a piston rod, and of a keyway in a shaft drive, etc., etc., are extremely common in practice. Again, considerations of cost permit of variations in surface

⁴⁴. See "Stress Concentrations Produced by Fillets and Holes," Timoshenko. Rept. Brit. Assoc. 1926, p.352.

finish ranging from rough machining to finish grinding. It is well known that the mathematical theory of elasticity indicates clearly that a uniform stress distribution will not be obtained at any cross section where the form or size is changing and that where the change is rapid, the stress concentration effects produced will be large. The mathematical theory is based on the assumption of an elastic and isotropic material, which conditions do not obtain, even approximately, in engineering materials of construction. Further, the invaluable property of plastic deformation by yielding undoubtedly plays an enormous part in practice by defeating stress concentration effects as far as *actual rupture* is concerned. Again, the ultimate *static* strength of a specimen containing a sudden discontinuity such as a Vee-groove, based on the area at the bottom of the groove may exceed that of the normal section, although the shock resisting properties are usually very greatly reduced; the reasons for these established facts are well understood and need not be mentioned here. But it is necessary to emphasise that when metals are subjected to fatigue stresses the effects of stress concentrations produced in this way may be extremely serious, and, in fact, in some cases, approximate to their full theoretical effect. That these effects are not adequately realised even by designers of high speed machinery is proved by the large number of cases that occur where fatigue failure is directly attributable to insufficiently large fillets on crankshafts, toolmarks inside connecting rods, file marks (even on such articles as copper pipes), etc. Although sudden discontinuities of section and surface finish can be reduced to the same general case of stress concentrations, it may be convenient, from the practical point of view, to consider each separately.

(i) EFFECTS OF SUDDEN DISCONTINUITIES OF SECTION UPON THE ENDURANCE LIMIT.

As typical examples may be cited some experimental results by Stanton & Bairstow⁴⁵ on specimens subjected to reversed direct stresses, and by Moore

TABLE I.
EFFECT OF DISCONTINUITIES OF SECTION UPON ENDURANCE LIMIT.

Type of Applied Stressing.	Material.	Ultimate Tensile Strength : Tons per sq. inch.	Endurance Limits (Ratios).			
			Specimens without rapid changes of Section.	Specimens with moderately rapid changes of section (small fillets).	Specimens with Whitworth Vee Thread.	Specimen containing sudden changes of section (square shoulders).
Reversed Direct Stresses (Stanton and Bairstow).	0.65% C. Steel	47.6	1	0.68	0.69	0.18
	0.45% " "	43.6	1	0.72	0.70	0.17
	0.33% " "	28.3	1	0.72	0.71	0.55
	0.07% " "	21.9	1	0.72	0.74	0.64
	0.03% C. Wrought Iron	23.8	1	0.81	0.77	0.60
Reversed Bending Stresses (Moore and Kommers).	0.49% C. Steel	43.2	9.85" radius Transition Curve. 1	1" radius Transition Curve. 0.99	0.25" Transition Curve. 0.87	90° Square Sharp Vee Shoulder Notch. 0.37 0.47

& Kommers⁴⁶ where reversed bending stresses were employed. The results are summarised in Table 1.

These results are sufficient to show that in parts subjected to alternating stresses, every precaution must be taken to avoid sudden discontinuities of section and that where changes of section are unavoidable, effort must be made to reduce their effects by employing transition curves of sufficiently large radius. (It is, perhaps, hardly necessary to add, in connection with the bending results recorded in Table 1, that the reductions recorded only apply to the actual specimens used where the nominal specimen diameter of 0.4 inch was reduced to 0.275 inch. With larger-sized rods, correspondingly greater values of the transition curve must be employed, although the actual scale effect has not been determined.) As a general rule, it may be said that stress concentration effects become much more pronounced as the hardness of the material increases. For example, Haigh investigated the effects of a small circular hole drilled in specimens subjected to repeated tensile stresses. The theoretical concentration effect of such a small circular hole is 3. The first material employed was a mild steel⁴⁷ in which the upper stress of the cycle was in the neighbourhood of the static yield point of the material. In this case the effect of the presence of the hole was insignificant when compared with the theoretical stress concentration; evidently, marked plastic yielding had effected re-distribution of stress, and/or a local hardening of the material. Entirely different results, however, were obtained with a cold rolled steel⁴⁸ possessing little ductility, for the endurance limit was reduced in the ratio $\frac{1}{2.15}$ as compared with the

full theoretical value of $\frac{1}{3}$. In similar tests on a medium carbon steel which had been cold-worked to an unusually high degree, I found the stress concentration effect produced by a circular hole of a higher order still, namely

$$\frac{1}{2.3}$$

A point of considerable theoretical interest may be mentioned. Although it is true that the effects of stress concentrations are undoubtedly modified by the ductility of the material, the value of the latter cannot be determined by such properties as the elongation or contraction of area at fracture as disclosed by a tensile test, but are probably controlled by the measure of ductility occurring within the applied range of stress during fatigue. For example, cast iron is normally regarded as a brittle metal, yet the recent experiments of Moore, Lyon & Inglis⁴⁹ shew that the discrepancy between theoretical and effective stress concentration effects in cast iron is greater than for some of

46. Bulletin No. 124, Univ. Ill., 1921.

47. Rept. Brit. Assoc. Section G. 1923.

48. Rept. Brit. Assoc. Section G., 1924.

49. Bulletin No. 164, Univ. Ill.

the more ductile wrought ferrous metals. This apparent analogy is explained, I suggest, by a reference to the curved form of the tensile stress-strain curve associated with cast iron, which shews that this material has no appreciable range of primitive elasticity.

(ii) EFFECT OF SMALL SURFACE DEFECTS ON THE ENDURANCE LIMIT.

Many researches have shewn the effects of varying degrees of surface finish upon the fatigue properties of metals, but in very few cases have any attempts been made to discover the true shapes of the small discontinuities present and thus to compare their actual and theoretical effects. The work of Thomas⁵⁰, however, is a notable exception and may be discussed briefly. The experiments were aimed at determining the effect, upon the endurance limit of a 0.33% Carbon Steel, of scratches and grooves of known size and shape. Endurance tests were made on a Wohler Machine while the actual sizes and shapes of the discontinuities were determined by the use of gelatine casts of the various surfaces. In this way the observed values of the reduction in fatigue ranges obtained were compared directly with the estimated theoretical stress concentration effects deduced from the mathematical work of Suyehiro⁵¹ and Inglis⁵², the soap-film method of Griffith⁵³, and the modifications for torsional and bending stresses as investigated by Griffith⁵⁴. The reductions in fatigue strength due to vee notches, amounting to 13½%, 23½% and 29% are sufficiently serious, but are small compared with the corresponding calculated theoretical effects, namely, 66½%, 78% and 82½% respectively. Moreover, the theoretical effect is dependent only on the shape of a discontinuity and is independent of its actual size, but Thomas found that the larger grooves in which the depth of the scratch was about 0.005 inch produced a much greater reduction in fatigue strength than the smaller grooves of depth 0.002 inch and lesser depths.

TABLE 2.
EFFECT OF VARIOUS WORKSHOP FINISHES (THOMAS).

Type of Finish.	Estimated Maximum Reduction in Fatigue Strength (per cent.).
Turned	12
Coarse File	18 to 20
Bastard File	14
Smooth Emery	7½
Coarse Emery (No. 3)	6
No. 1, Emery	4
Finer Emery (O or FF)	2 or 3
Fine Carborundum	2 or 3
Fine Ground Finish... ..	4
Accidental Scratches (Maximum Found) ...	16

50. No. 860, Repts. & Mem. Series, Aero. Res. Ctee., 1923.

51. Engineering, September 1st, 1911, p. 280.

52. Trans. Inst. Naval Archi., Pt. 1., 1913, p. 219, etc.

53. Rept. No. T. 1275, Adv. Ctee. for Aero. B.2.g., Dec., 1918.

54. See "Report on the Materials of Construction used in aircraft and Aircraft Engines" C. F. Jenkins, 1920, H.M. Stat. Office.

Using these data, he investigated the sizes and shapes of scratches left on several steels (including tool steel), aluminium, and cast iron, and deduced the extremely interesting results quoted in Table 2.

As examples of engineering details which have been found to suffer especially from stress concentration effects may be mentioned plate and coil springs. Laminated springs as used for lorries, etc., have given considerable trouble, particularly during the war, and their performance in practice compares extremely unfavourably with that of similar spring material when tested under laboratory conditions. The subject has received, and is still receiving, detailed study at the National Physical Laboratory, where machines have been designed for testing laminated springs as a whole, also spring leaves, both under fatigue stresses. A feature of the design of some springs of this type is that clamping or other contact stresses are applied at the point of maximum bending moment, also in the majority of cases, no attempt is made to remove surface irregularities caused in manufacture or the particularly dangerous quenching cracks set up by heat treatment⁵⁵. The typical results given in Table 3 are instructive.

TABLE 3.

TESTS SHOWING EFFECTS OF CLAMPING STRESSES AND SURFACE DEFECTS (HANKINS).

Material.	FATIGUE RANGES (Tons per square inch).		
	COLUMN 1. Specimens of uniform width (clamping stresses and surface defects).	COLUMN 2. Specimens with transition curves (no clamping stresses: surface defects only).	COLUMN 3. Specimens with correct transition curves also prepared surfaces.
0.6% Carbon Steel. (Hardened and Tempered)	± 20.0 (0.53)	± 27.0 (0.71)	± 38.0 (1.0)
Tool Steel	± 18.0 (0.69)	± 24.5 (0.94)	± 26.0 (1.0)
Mild Steel	± 10.5 (0.73)	± 14.0 (0.97)	± 14.5 (1.0)

For each material the effect of the stress concentration due to end clamping is serious, with a maximum value for the hard spring steel. The effect of the surface defects is very small in the case of the mild steel but becomes serious in the spring steel.

Surface defects may become of even greater danger in coiled springs, and Lea & Heywood⁵⁶ have published some significant tests in this connection. Fig. 3 illustrates the results of these tests on a Chrome-Vanadium steel in the form of coiled springs, and, also, as prepared specimens. In the discussion of this paper Hankins submitted some data which confirmed the conclusion that

55. In some automobile practice, however, the surfaces of laminated springs are carefully ground after forming and heat treatment operations have been completed.

56. Proc. Inst. Mech. Engrs. Vol. 1, 1927. p. 303.

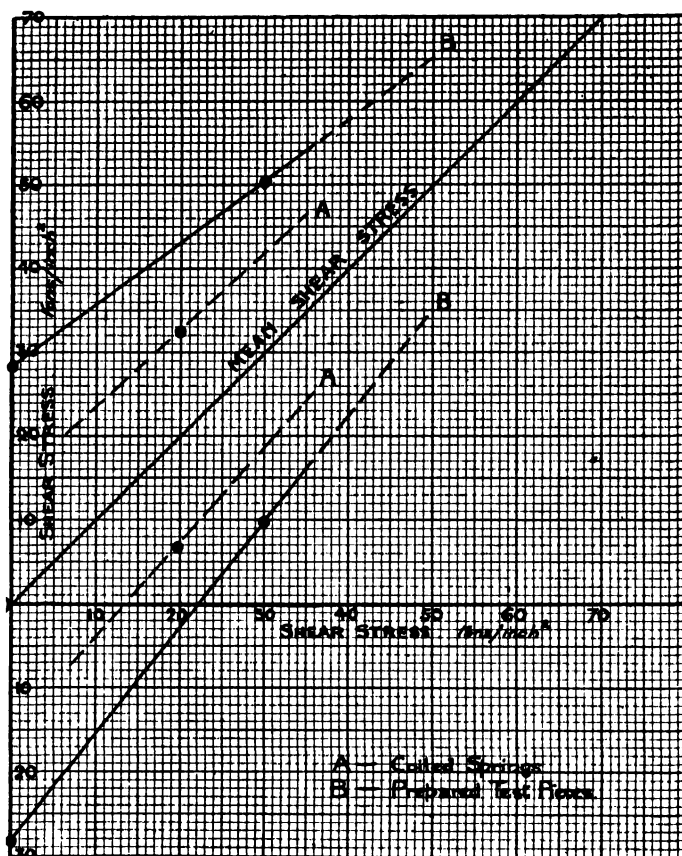


FIG. 3—Curves showing the influence of surface defects upon the fatigue strength of coiled springs.

the discrepancies between the test results must be ascribed primarily to surface defects.

It has often been suggested that results such as some of these described above are sufficient to prove that the mathematical laws of elasticity may be dismissed by designers as leading to erroneous conclusions. This is a fallacy based upon a misunderstanding of the principles on which these laws are based. The theory applies to isotropic material in a state of elasticity. Now, engineering materials are not isotropic, but it is remarkable how mathematical laws still apply as long as the second condition of elasticity obtains. Therefore, to check the truth of the laws, we must not look to the effects of stress-concentrations on *ultimate* failure, or on *fatigue* failure, but on *elastic* failure. Provided a certain very small depth (usually of the order of 10^{-3} or 10^{-4} inches) of the discontinuity is exceeded, the expected stress concentration figure is, usually, closely realised. One example will suffice to illustrate this point.

TABLE 4.

SUMMARY OF TORSIONAL STATIC AND FATIGUE TESTS ON SHAFTS CONTAINING A DISCONTINUITY IN THE FORM OF A STANDARD KEY-WAY (GOUGH).

			0.65% Carbon Steel.			0.02% Carbon Steel.		
			Solid Shaft.	Shaft with narrow key-way.	Shaft with wide key-way.	Solid Shaft.	Shaft with narrow key-way.	Shaft with wide key-way.
Static Tests.	Values of the Stiffness factor.	Experimental. Calculated.	0.00251	0.00236	0.00229	0.00251	0.00234	0.00222
	Torque at limit of proportionality.	Experimental (in lbs.). Ratio.	—	0.00239	0.00233	—	0.00239	0.00233
	Stresses at limit of proportionality (tons per sq. in.).	Experimental. Calculated (at bottom of key-way)	365	276	276	122.5	95.0	95.0
	Maximum Torque at fracture (Ratio).	Ratio. Experimental.	1	0.756	0.756	1	0.776	0.776
			12.9	—	—	4.4	—	—
Fatigue Tests.			—	12.3	12.6	—	4.3	4.5
	Experimental Limiting ranges of Torque (Ratio).		1	0.963	0.945	1	0.954	0.895
			1	0.80	0.80	1	0.88	0.88

A series of tests was made on model shafts, 0.400 inch in diameter ; some shafts were solid, others had a keyway of standard width and depth (to scale) ; a third series had keyways of standard depth but half standard width. Two materials were investigated, Armco Iron (Tensile Strength 18.7 tons per sq. inch) as representing a very ductile material, also a medium carbon steel (Tensile Strength 50.0 tons per sq. inch), representative of harder steels.

The results are very briefly summarised by Table 4 which requires some explanation. Using formulæ developed by Griffith⁵⁷ derived from the soap-bubble method based on Pranel's theorem, the stiffness factors for the various shaft sections are calculated (see Table). Very accurate statical torsional tests were then made on the shafts and the experimental stiffness factors and the torques at the limits of proportionality were determined. The agreement between the experimental and calculated stiffnesses is seen to be very close. Using the stiffness factors and the torques at the limit of elasticity, the maximum stress of the section (occurring at the bottom of the keyway) can be calculated and, provided the theoretical stress concentration has been realised, should

agree with the stress at the elastic limit of the solid shaft. The results shew that an extremely close measure of agreement was reached. Thus, within the elastic range the theoretical stress concentration has been realised. Before fracture under static torsion occurs, however, the shaft sections have been so much distorted that stress concentration effects have been practically eliminated by plastic yielding. Note also that the fatigue ranges are *not* reduced to the extent indicated by the theory, and that the actual reduction is much less for soft iron than for the harder steel; the fatigue specimens tested at ranges of stress in the neighbourhood of the limiting ranges shewed no appreciable distortion.

Other publications, ⁵⁸, ⁵⁹, ⁶⁰, ⁶¹, dealing with stress concentrations in theory and practice are brought to the attention of those interested.

Figure 4 is interesting, as it shows that under fatigue stressing a machine component will not always break at its weakest section. It represents the results of some fatigue tests⁶² I made to discover the effect of a discontinuity (in the form of a vee-notch) on the fatigue strength. The parallel and notched sections of the specimen were in tandem and subjected to a uniform bending moment. The results demonstrate that any form of test—such as the "Arnold" test—in which specimens are broken in a small number of reversals, are entirely useless in estimating the true relative fatigue ranges of metals.

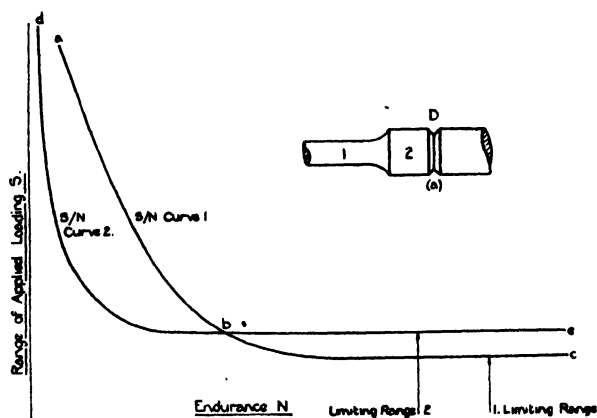


FIG. 4—S/N curves obtained from test pieces containing a parallel cylindrical portion (1), and an enlarged portion (2) containing a discontinuity (a).

58. Griffith. "Stress Concentrations in Theory & Practice," Rept. Brit. Assoc. Section G., 1920, p. 316.

59. Gough. "Fatigue of Metals," Chapter V.

60. Griffith. Phil. Trans. Roy. Soc. A., 221.

61. R. R. Moore. Proc. Amer. Soc. Test. Mat. Vol. 26, Pt. 2, 1926, p. 255.

62. Repts. & Mem. Series, Aero. Res. Ctee., No. 864, April, 1925.

SECTION III.

THE EFFECT OF TEMPERATURE ON FATIGUE STRENGTH.

The effect of temperature on the strength of materials of construction is of very great theoretical and practical importance. On the theoretical side, temperature is one of the fundamental conditions controlling the resistance to deformation or fracture of solid matter. On the practical side, modern engineering requirements demand a range of materials possessing suitable resistance to prolonged loading and/or to fatigue stressing at temperatures which may be very high or very low or may vary widely. At the one extreme, we have the low temperature conditions associated with refrigerating plants and the high altitude aeroplane; towards the other extreme are found those temperatures to which certain parts of steam boilers, engines and turbines, also internal combustion engines, are subjected, sometimes continuously for long periods. At low temperatures the practical problem lies not so much in the direction of providing materials possessing sufficient statical *strength* as sufficient resistance to withstand *shocks*; these demands appear to have been met in a fairly satisfactory manner. But the marked tendency of engineering materials to "flow" or "creep" at elevated temperatures, even under moderate stresses, presents a serious problem at a time when marked increases in the temperature and pressure of working conditions are being explored as a means towards higher efficiency. In fact, a definite limit is placed at present on development in this direction by the inability of existing materials to resist the required working conditions, and fundamental researches for new materials of construction are in progress at the National Physical Laboratory and elsewhere.

As far as I am aware, there are no published test data of fatigue tests conducted at temperatures *lower* than 15° to 20° C. Fatigue testing at elevated temperatures⁶³ has received detailed study by Tapsell⁶⁴ at the National Physical Laboratory, by Lea⁶⁵ at Birmingham, and by Moore⁶⁶ at Illinois.

I hope to shew that it is extremely unwise to attempt to discuss the results of fatigue tests on metals conducted at elevated temperatures, without giving consideration to the general behaviour of these metals under prolonged statical loading at the same temperatures. For this purpose it will not, perhaps, be out of place to consider the broad general results of such statical tests. In order to do this I have chosen some typical test data obtained at the National

63. As a matter of historical interest, the first recorded tests appear to have been carried out by Unwin; See Proc. Inst. Civ. Engrs. Vol. CLXVI, p. 117.

64. (a) Engineering, November 11th, November 20th, and December 11th, 1925.

(b) Jour. Inst. Metals, Vol. XXXV, No. 1, 1926.

(c) Eng. Res. Special Reports Nos. 1 & 2, D.S.I.R., 1927. (H.M. Stationery Office).

65. (a) Proc. Inst. Mech. Engrs. Dec., 1924.

(b) Engineering, October 3rd & 10th, 1924.

(c) Engineering, February 23rd, 1923.

66. Bulletins Nos. 152 & 164, Engineering Expt. Station, University of Illinois.

Physical Laboratory by Tapsell, for the reason that these tests were made under most carefully controlled conditions of temperature, and also, that this investigator has published the most complete set of static *and* fatigue tests at elevated temperatures.

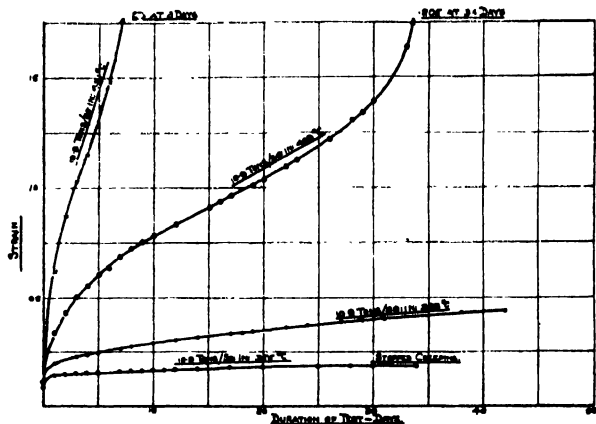


FIG. 5—Curves showing the relation between strain (creep) and duration of test for different temperatures. Armco Iron at 10.9 tons per sq. inch.

The strength of a material at high temperatures is dependent on the time the material is under stress; when that time is short the strength approaches a maximum value. Similarly, when a specimen is subjected to a steady tensile *load*, the form of the strain-time curve depends upon the temperature at which the test is conducted. Figure 5 shews some of Tapsell's results on Armco Iron. Several specimens were each loaded to the same initial stress at various temperatures, accurate extensometer readings of strain being taken at regular intervals. From these readings, the rate of extension, or "flow" or "Creep," can be calculated at various stages in the test. The curves of Figure 5 have some general characteristics. During the early stage of each test, the initial high rate of creep gradually diminishes (1st stage) until the second stage is reached, when a constant rate of creep appears to be attained. These two stages can be clearly seen in all four curves of Figure 5. In the top two curves, the conclusion of the second stage is marked by a point of inflexion in the curve, after which the rate of creep increases at an increasing rate, finally leading to fracture of the test piece. The rates of creep during the second stages—each representing the minimum rate at the particular temperature—are then plotted against temperature. The point at which this curve, or curve produced, passes through the zero rate ordinate is taken as the "limiting creep temperature" at the particular stress used. Similar groups of curves can be obtained using various *stresses* at a constant temperature, giving the "limiting creep stress" at that temperature. The limiting creep stress becomes, therefore, that stress under which at some stage the rate of creep becomes zero.

For the determination of this quantity, relatively long tests are necessary and the order of accuracy of measurement must be high. These conditions have not been complied with by some other investigators using this method; tests lasting only a few hours or days are of very little value.

In Mr. Tapsell's experience, he has not encountered a case in which the strain-time curve has reached zero slope, and subsequently has increased in slope, except for certain metals which fracture at high temperature by inter-crystalline failure.⁶⁷ This fact suggests that the limiting creep stress obtained in this way really represents the stress which the material can withstand for an indefinite period without further deformation or ultimate fracture. If a number of test pieces are tested at various stresses at a constant temperature and the time to fracture is plotted logarithmically against stress ($\log T/\log S$), a straight line is usually obtained. Elsewhere⁶⁸ I have plotted Tapsell & Bradley's creep test data for a 70/30 Ni. Cu. Alloy. Remembering the manner (see Fig. 1, Section 1) in which the existence of a true limiting range of stress at air temperature has been indicated by such plotting, the creep stress data are seen to be insufficient to disclose a discontinuity in the curve. This applies, as far as I am aware, to similar plottings of all published creep data. The present position, therefore, can be summarised by saying that the existence of a true limiting creep stress at elevated temperatures has not yet been established, and many more prolonged tests are needed; the *rate of creep* tests, however, strongly *suggests* that such a limiting stress does actually exist at certain elevated temperatures.

FATIGUE TESTS.

(i) *Reversed Direct Stresses.* Table 1 contains most of the available published data on fatigue at elevated temperatures under reversed direct stresses. All the results given were obtained using the Haigh Machine operated at a speed of about 2,000 r.p.m. For convenience, these data have been tabulated at intervals of 100°C. of temperature and have been taken from curves published by the investigators. Where a figure is enclosed by brackets, insufficient data have been obtained at or near the particular temperature concerned to establish the value given, and *no conclusions* should be drawn from the *shape* of the Stress/temperature curve at *these* points. (This is important.) Limiting creep stress values (as stated by the investigators) are included.

The test data of Table 1 are expressed graphically in Figure 6. Several interesting features are apparent. In most cases the maximum value of the endurance limit does not occur at air temperature but in the area 300°C./450°C., while the value at 100°C./200°C. is less than that at air temperature. Another very significant feature of the tests is seen by a comparison of the fatigue and creep stress data given in Table 1. It will be seen that the decrease in

67. A paper on this interesting special case of high temperature phenomena will be published shortly.

68. See Discussion, Jour. Inst. Metals, Vol. XXXV, No. 1, 1926, p. 93.

TABLE I.

RESULTS OF FATIGUE TESTS AT ELEVATED TEMPERATURES (REVERSED DIRECT STRESSES—HAIGH MACHINE).

Material.	Ref. No.	Investigator.	*	Temperature of Test. (See note in Text).								
				18°C.	100°C.	200°C.	300°C.	400°C.	500°C.	600°C.	700°C.	
Armco Iron. (0.02% C.) Normalised.	1	Tapsell & Clenshaw.	E.L. (10) E.L. (R) L.C.	11.9 1.00 —	10.7 0.90 —	11.4 0.96 28.0	14.9 1.25 16.3	12.9 1.08 8.4	5.8 0.44 —			
0.06% C. Steel.	2	Lea.	E.L. (5) E.L. (R)	13.6 1.00	(12.8) (0.94)	(12.8) (0.94)	13.6 1.0	17.5 1.29	17.9 1.32			
0.14% C. Steel.	3	Lea.	E.L. () E.L. (R) L.C.	15.0 1.00 —	(15.0) (1.00) —	15.0 1.00 33.0	17.9 1.19 31.0	18.6 1.24 14.0	16.0 1.07 4.0	14.0 0.93 1.0		
0.17% C. Steel. Normalised.	4	Tapsell & Clenshaw	E.L. (10) E.L. (R) L.C.	12.5 1.00 —	12.3 0.98 —	12.3 0.98 —	16.0 1.28 26.0	16.8 1.34 14.5	11.7 0.94 5.0	6.8 0.54 —		
0.24% C. Steel. Normalised.	5	Tapsell & Clenshaw	E.L. (10) E.L. (R) L.C.	13.3 1.00 —	12.3 0.92 —	12.3 0.92 28.0	16.0 1.20 28.0	17.0 1.28 15.7	13.0 0.98 5.0	7.3 0.55 —		
0.51% C. Steel. Normalised.	6	Tapsell & Clenshaw	E.L. (10) E.L. (R) L.C.	14.7 1.00 —	13.9 0.95 —	13.9 0.95 —	19.3 1.31 31.0	19.2 1.30 16.5	14.3 0.97 5.0	7.2 0.49 —		
0.53% C. Cast Steel.	7	Tapsell & Clenshaw	E.L. (10) E.L. (R) L.C.	12.2 1.00 —	12.9 1.06 —	(12.9) (1.06) —	13.0 1.07 27.0	(11.3) (0.93) 12.0	8.7 0.71 —	7.0 .57 —		
Ni. Cr. Steel. 3½% Ni. 0.60% Cr. 0.35% C.	8	Lea.	E.L. (5) E.L. (R)	26.0 1.00	(22.9) (0.88)	(21.2) (0.82)	20.0 0.77	(20.0) (0.77)	20.0 0.77	19.6 0.75	18.7 0.72	
80/19 Ni. Cr. Alloy.	9	Tapsell & Bradley.	E.L. (10) E.L. (R) L.C.	15.0 1.00 —	(15.1) 1.01 —	15.7 1.05 —	17.7 1.18 —	17.7 1.18 —	(16.5) (1.10) 24.0	15.7 1.05 15.0	15.2 1.01 6.0	
70/30 Ni. Cu. Alloy (2.35% Mn.)	10	Tapsell & Bradley.	E.L. (10) E.L. (R) L.C.	15.9 1.00 —	13.3 0.84 —	12.7 0.80 —	12.7 0.80 —	(12.6) (0.79) 24.0	11.7 0.74 10.2	8.9 (0.56) 2.2	— <1.0	
Cast Iron 1.97% G.C. 0.46% C.C. 2.07% Si.	11	Haigh.	E.L. (6) E.L. (R)	9.6 at 18°C. 8.5 at 350°C. 9.0 at 500°C. 1.00 at 18°C. 0.89 at 350°C. 0.94 at 500°C.								
0.65% C. Steel. Normalised.	12	Tapsell.	E.L. (10) E.L. (R)	10.5 at 18°C. 14.9 at 300°C. 1.00 at 18°C. 0.76 at 300°C.								
Al. Si. Alloy. (12.7 Si). Cast.	13	Tapsell.	E.L. (10) E.L. (R)	3.8 at 18°C. 2.8 at 180°C. 1.00 at 18°C. 0.74 at 180°C.								

* E.L. (N) = Endurance Limit (Tons per Sq. Inch) on a reversals basis of N millions.
 E.L. (R) = Ratio $\frac{\text{Endurance Limit at } t^{\circ}\text{C.}}{\text{Endurance Limit at } 18^{\circ}\text{C.}}$
 L.C. = Limiting Creep Stress (Static Tensile), Tons per Sq. Inch.

fatigue strength is much less than the fall in the creep stress value as the temperature of test increases. In most cases, a temperature is reached at which the endurance limit is greater (in some cases, many times greater) than the limiting creep stress. The point where these values are equal is indicated on the diagram by the sign $\oint$. This feature will be discussed later.

(ii) *Reversed Bending Stresses.* The results given in Table 2 were all obtained in the Engineering Experiment Station of the University of Illinois using a modified type of Wohler Machine operating at a speed of 1,500 r.p.m. The data enclosed by brackets again refer only to interpolated values. The values of the static strength under "prolonged loading" (marked P.L. in Table 2)

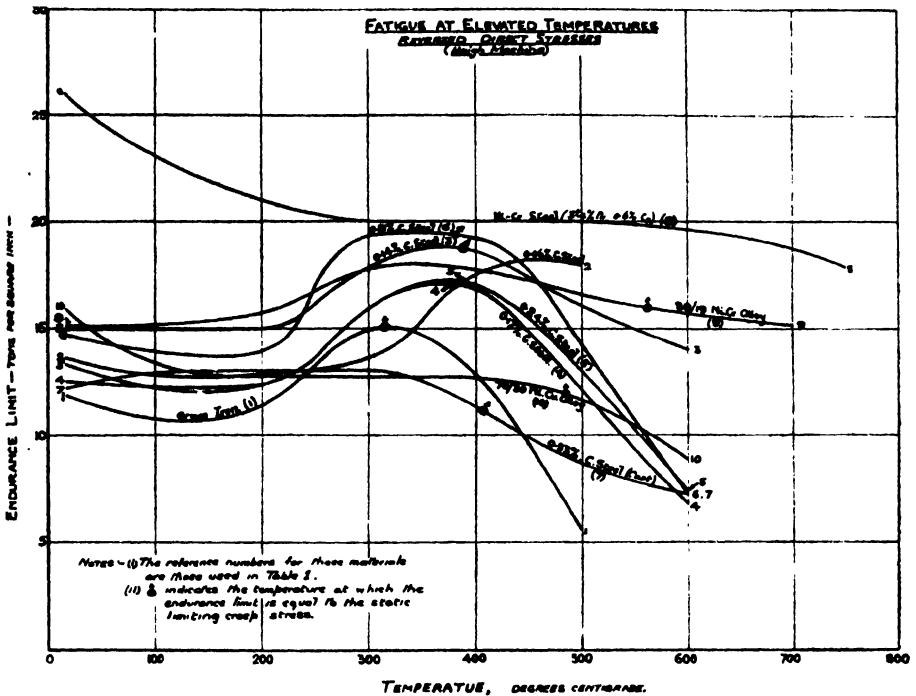


FIG. 6—Fatigue at elevated temperatures under reversed direct stresses (Haigh machine).

were obtained from tests lasting only from 12 to 72 hours. In these tests, the loading was increased by increments, a further increment not being added until the strain due to the previous load had ceased to increase “appreciably.” There is little doubt that these “prolonged loading” strength values greatly exceed the *limiting* creep stresses as determined by Tapsell or Lea. They have some value, however, as indicating, in a very approximate manner, the static strength of the materials at elevated temperatures. Table 2 shows that the prolonged loading values diminish, with increase in temperature, at a much greater rate, than do the endurance limits, and in two cases (the 1.02% carbon steel and cast iron) the curves cross within the limits of temperature investigated.

The results of Table 2 are plotted in Figure 7. The forms of these curves (for reversed bending stresses) are generally similar to those of Figure 6 (for reversed direct stresses) in the temperature range 400°C./550°C. No experimental data were obtained to shew if a local minimum value of the endurance limit exists at 100°C./200°C. (In addition to these tests Hankins** has carried out reversed bending stresses on a number of alloys of aluminium both at air temperature and at 150°C. As they extended only to two million reversals, however, the results are somewhat inconclusive.)

TABLE 2.

RESULTS OF FATIGUE TESTS AT ELEVATED TEMPERATURES. (REVERSED BENDING STRESSES—WOHLER MACHINE*).

Material.	Ref. No.	Investigator.	*	Temperature of Test. (See Note in Text).							
				18°C.	100°C.	200°C.	300°C.	400°C.	500°C.	600°C.	700°C.
Cast Iron. 2.76% G.C. 0.68% C.C. 1.10% Si.	1	Moore Lyons & Ingilis.	E.L. (10)	5.3	—	—	—	—	4.8	4.2	3.3
			E.L. (R)	1.00	—	—	—	—	0.91	0.79	0.62
			P.L.	13.4	13.2	12.7	(12.1)	11.4	7.4	3.8	2.8
0.49% Carbon Steel. Normalised.	2	Moore & Jasper.	E.L. (10)	15.6	(16.5)	(17.0)	17.1	17.9	16.5	10.3	
			E.L. (R)	1.00	(1.06)	(1.09)	1.10	1.15	1.06	0.66	
			P.L.	41.0	41.5	43.2	48.2	38.4	19.6	11.6	
1.02% Carbon Steel. Hardened.	3	Moore & Jasper.	E.L. (10)	47.0	(44.6)	41.0	37.0	36.1	30.8	24.5	
			E.L. (R)	1.00	(0.95)	0.87	0.81	0.77	0.66	0.52	
			P.L.	89.5	(87.0)	84.5	67.0	46.0	30.8	22.3	
3½% Nickel Steel. Hardened and Tempered (425°C.)	(a)	Moore & Jasper.	E.L. (10)	34.0	(34.8)	35.7	35.3	33.5	27.7	24.6	
			E.L. (R)	1.00	(1.02)	1.05	1.04	0.99	0.81	0.72	
			P.L.	74.0	74.0	72.5	67.0	54.5	31.3	26.8	
3½% Nickel Steel. Hardened and Tempered (650°C.)	(b)	Moore & Jasper.	E.L. (10)	33.0	(33.0)	33.0	32.2	30.4	26.4	23.6	
			E.L. (R)	1.00	(1.00)	1.00	0.98	0.92	0.80	0.72	
			P.L.	56.0	(53.5)	53.5	53.5	47.8	27.7	19.2	
High Ni. Cr. Steel. (19% Ni. 8% Cr.) Annealed.	5	Moore & Jasper.	E.L. (10)	21.6	(23.7)	(23.2)	22.5	21.4	19.6	17.9	
			E.L. (R)	1.00	(0.96)	(0.94)	0.92	0.87	0.80	0.73	
			P.L.	50.0	47.8	45.5	44.6	44.0	38.2	34.4	

* E.L. (10) = Value of Endurance Limit, in Tons per Sq. Inch, on a 10 millions reversals basis.
Endurance Limit at t°C.E.L. (R) = Value of Ratio
Endurance Limit at 18°C.

P.L. = Static Tensile Strength, in Tons per Sq. Inch, under prolonged loading.

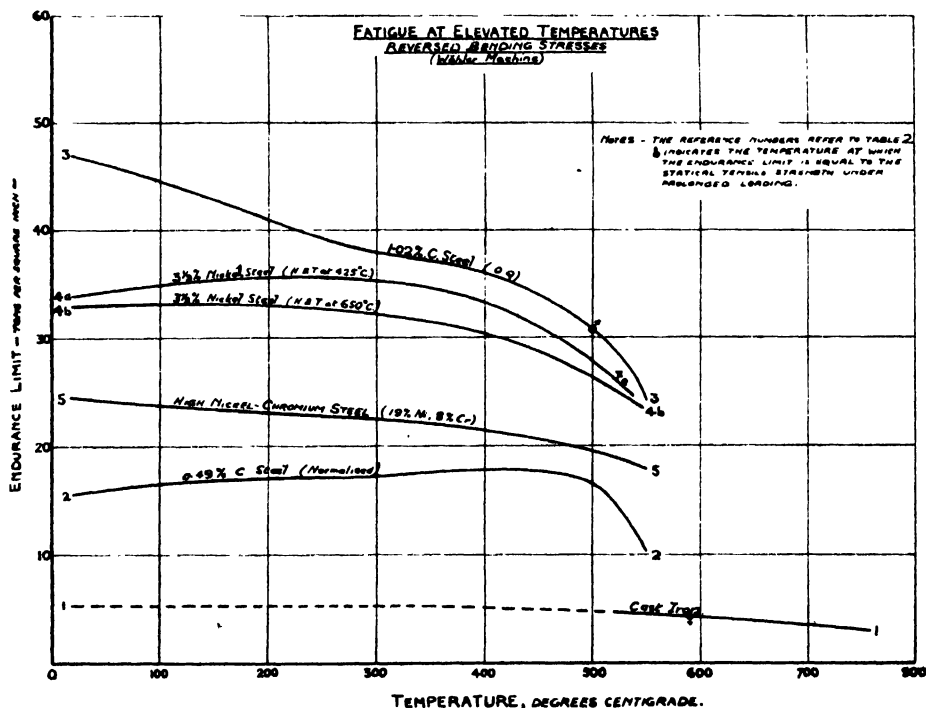


FIG. 7—Fatigue at elevated temperatures under reversed bending stresses (Wöhler machine).

The outstanding feature about fatigue testing at elevated temperature is the ability of specimens to withstand, at certain temperatures, without fracture, many millions of reversals of a cycle of stress of which the maximum stress greatly exceeds the static limiting creep stress. Figure 8 (which relates to the

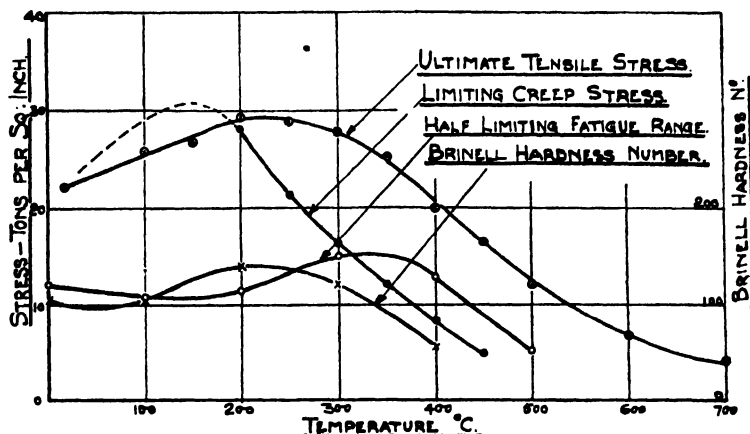


FIG. 8.—Mechanical properties of metals at elevated temperatures. Comparison curves for Armco Iron.

Armco Iron referred to in Table 1) brings out this point in a marked manner. Let us discuss several possible explanations of this fact. In the first place, there may be a real speed effect, *i.e.*, at the high speeds of reversals used a material may develop a real fatigue range (for an indefinitely large number of reversals) the upper stress of the cycle exceeding the static creep limit. To establish this point it will be necessary to carry out a series of very lengthy endurance tests at widely different cyclic speeds, all the tests being made on testing machines of the same type. No tests of this kind have yet been made. Secondly, the fatigue range may be associated with a certain limiting extension which in turn may depend on the *mean* stress of the cycle. If this is correct, it is useless to compare the results of *reversed* stress fatigue tests with those of *tensile* creep tests. Both Lea and Tapsell, however, have carried out fatigue tests at elevated temperatures in which cycles of wholly tensile stresses have been employed and of which the mean stress has been equal to or greater than the static limiting creep stress at that temperature. Typical results will be found in Table 3.

These tests show clearly that a specimen can withstand, without fracture, many millions of repetitions of a cycle of stress whose maximum stress and even mean stress exceed greatly the value of the static limiting creep stress. There remains a third possibility that a "time" effect becomes of consequence in fatigue tests at elevated temperatures, *i.e.*, the stresses are fluctuating at such a rapid rate that the "effective" time for which the maximum stress is applied during each cycle is so small that *very* lengthy endurance tests are

TABLE 3.

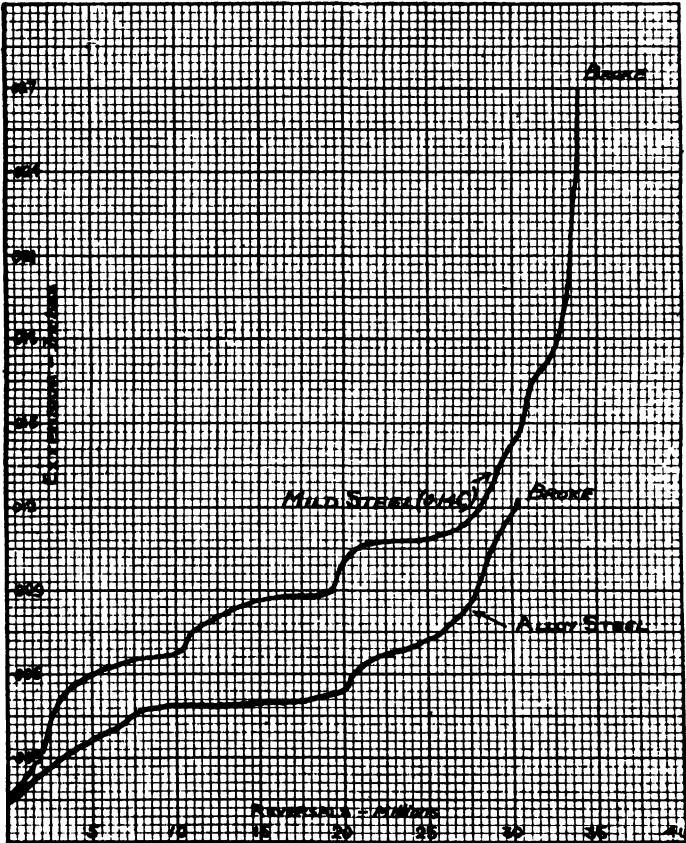
FATIGUE TESTS AT ELEVATED TEMPERATURES EMPLOYING CYCLES OF PULSATING TENSILE STRESSES.

Material.	Investigator.	Temperature of test.	Safe Range of stress (10^7 cycles) (Tons per sq. inch).	Mean Stress of cycle (Tons per sq. inch).	Limiting Static Creep Stress (Tons per sq. inch).
0.14% Carbon Steel.	Lea.	400° C.	8 to 22	15	14
		500° C.	8 to 22	15	4
0.17% Carbon Steel.	Tapsell & Clenshaw.	400° C.	0 to 26	13	14½
		500° C.	0 to 17	8½	5

required to disclose the true fatigue range, although at air temperatures endurance tests on 10^7 reversals basis are usually sufficient (with ferrous metals) to reveal the horizontal part of the S/N curve. A careful plotting of the published test data fails to show that the S/N curves for elevated temperatures tend to become horizontal within the maximum endurance investigated (up to 40×10^6 cycles), also, both Lea & Tapsell record fractures at endurance considerably exceeding 10^7 cycles. If, therefore, such fatigue tests are merely "delayed" creep tests, a record of the extensions occurring during a fatigue test should be informative.

Professor Lea has published two curves of this kind (Fig. 9). It will be seen that both the specimens endured over 30 millions of cycles of wholly tensile stresses before fracture. A striking similarity between these extension-reversals curves for fatigue loading and the extension time curves of Fig. 3 for static tensile loading is at once apparent. The work of Blairstown⁷⁰ and others has shewn that the extension-reversals curve for iron and steel, tested at *air* temperatures, become parallel to and remains parallel to the reversals base under a safe range of repeated tensile stresses. Figure 9 now suggests that a similar method of investigation is necessary at elevated temperatures before the existence and the evaluation of a real limiting stress can be said to be established. It would appear to be desirable to concentrate attention upon temperatures in the neighbourhood of that at which the creep stress curve crosses the apparent endurance limit curve. Extension-reversals curves (similar to Fig. 9) are required for various ranges of repeated tensile stresses extending to very lengthy endurance. If further research should shew that metals possess a definite fatigue range at elevated temperatures and that the range for repeated tensile stresses exceeds the static limiting creep stress at these temperatures, then it may be concluded that the hardening under the fatigue stressing exceeds that due to prolonged static loading. In connection with this point, Mr. Tapsell has carried out a very interesting experiment using 80/20 Ni. Cr. Alloy.

The estimated value of the statical limiting creep stress of this material at 700°C. was 6 tons per sq. inch. The endurance limit (10' reversals) at 700°C., was 15½ tons per sq. inch. A specimen which had successfully withstood 10' reversals of 15 tons per sq. inch was afterwards loaded statically in a creep testing machine at a stress of 10½ tons per sq. inch at 700°C. The specimen fractured after one day. A new specimen, loaded to 10½ tons per sq. inch in the creep testing machine fractured after 2½ days. As creep test results are somewhat irregular the difference between endurance of 1 and 2½ days are probably insignificant, but the results indicate, in a general way, that the specimen had not acquired, due to the fatigue stressing, any appreciable increased resistance to creep under static tensile loading.



	Mild steel.	Alloy steel.
Temperature °C.	= 446	450
Mean stress	= 10 tons/sq. inch.	10 tons/sq. inch
Maximum tension	= 17.05 tons/sq. inch	25.1 tons/sq. inch
Minimum tension	= 2.95 tons/sq. inch	-5.1 (Compression)
Range	= 14.10 tons/sq. inch	30.2

FIG. 9—Curves showing creep of metals under fatigue (direct stresses).

To sum up, it appears that the existence of a fatigue range at elevated temperatures still remains as an uncertainty, while the evidence available indicates that the lengthy endurances observed under high ranges of rapidly applied stress are probably really due to a "time" or "delayed creeping" phenomenon. These facts are of importance as affecting engineering design. In cases where permanent deformation is permissible and a very lengthy life only is required of a machine or structural component subjected to fatigue stressing, the basis of design should be the endurance limit in the range of temperature in which the statical creep limit *exceeds* the endurance limit. For higher temperatures, the statical creep limit only should be considered. If the circumstances do not permit of deformation occurring under load, the endurance limit and creep limit alike must be rejected in favour of the further restricted value of the limit of elasticity at the particular temperature.

NOTES ON BOOKS.

PHOTOGRAPHIC ART SECRETS. By Wallace Nutting, D.D. London: Chapman and Hall, Ltd. 12s. 6d. net.

The word "art," especially when used in connexion with photography, has been charged with so many different implications that no reader is likely to approach this book with any very fixed idea of what such a title may be taken to promise. One gathers from a few references in the text that Dr. Nutting's photographs find some sale amongst the American public, and presumably, therefore, many of them were taken with that object in view; but it must be said at once that the kind of art that is described and illustrated in these pages is hardly such as would commend itself at a modern exhibition, whatever may have been the case thirty years ago. In the fewest possible words, these photographs are faithful records of beautiful landscapes, for the most part, indeed, they are pleasing and satisfying examples of a school whose worst products may be examined in any "album of views."

Although this type of work is far, indeed, from being devoid of merit, it is yet open to the criticism that it contains nothing, save by a rare accident, that any observer could not have gathered at least as well from the original subject; and to the still more devastating criticism that the interest depends in large measure on one's interest in the locality depicted.

On the technical side, Dr. Nutting is more at home with practice than with theory. Many of his suggestions will be found well worth attending to by any photographer, whether "artistic" or not; though not all will command general agreement, as, for example, when he advises against the use of any form of exposure meter.

The book is arranged in titled sections, the contents of which in some cases are not very closely connected with the title, so that in the absence of an index it is sometimes difficult to rediscover particular points of interest. A lively and staccato style eases the reader's task; and much may be forgiven to an author who is capable of thus recommending the use of a ground glass focussing screen: "In addition there is the delight incident to gazing at the picture in the exquisite colours that appear in the glass. To many camerists (pardon the new word), the best thing about photography is the ground glass picture."

HOW TO DECORATE YOUR HOME. By W. T. Sainsbury. Simpkin Marshall.
London: 2s 6d.

A book that helps to keep down the basic expenses of life is welcome. Nowadays, when the new poor who have moved house like to give a painting party to their obliging friends, instead of inviting the builder to do the distempering, etc., it is useful to have a little book at hand with precise technical information. Mr. Sainsbury tells us exactly what to do. How to deal with ceilings, walls, floors; wood, plaster, iron. One section informs us how to keep brushes. All this is excellent.

We will not be able to follow his recommendations, however, when he is on the subject of wallpapers. "Do not," he says, "have the same paper in all the bedrooms. Plain, or almost plain stripes with a cut-out frieze representing wistaria, trailing roses or some other such design always look well." Cut-out friezes have always struck us as the abomination of desolation. The place of wistaria is outside the house.

This paternal booklet ends with a chapter on "How to Purchase a House." "Assuming that you have three children—two daughters to occupy one bedroom and one son another, and you require an extra bedroom for visitors . . ." There is nothing Mr. Sainsbury does not think of. In fact, remarkable value for half-a-crown.

AN APPROACH TO WINGED FLIGHT. By John D. Batten, M.A., LL.B. Brighton: The Dolphin Press, 1928.

Mr. Batten has been thoughtfully attracted by the action and behaviour in flight of various birds, including gulls in particular, and of numerous smaller birds and insects in general, and by the difference in the construction of the chief features of their wings and their details. A study of the mechanical operations of their flight has led to anatomical investigation of the muscles employed in the various movements of the wings of gulls and of pigeons. For this purpose his brother dissected for him a pigeon, and from this he gives an illustration enabling him to describe the proportions and relative positions and operation of the major and secondary muscles. Not that they are major or secondary in their importance, but in the strength necessary to the actions they have to perform. The greater pectoral he looks upon as the anti-gravity muscle or posture maintaining muscle and the secondary pectoral as concerned with the execution of movement. His examination of the muscles combined with his study of the wing movements of the bird in flight lead him to a mechanical imitation of the postural function of the pectoral muscles; and inferentially to that of their phasic activity. By a diagram illustration he describes a model apparatus in which the outspread wings are represented by light spars extending from the thorax and supported mechanically at about their centre of effort as angularly moved planes, the inner ends of the spars being for mechanical reasons carried within the thorax. From this model he deduces as one inference the effect of the gravitation tendency of the body weight of the bird, accompanied by the action of the pectoralis major and the forward movement of the bird owing to the rearward rush of the air through the wings. A bird, as he points out, does not fly by beating the air downward, but by driving it backwards. His consideration of this model and of the power of the major muscle leads him to a dissertation on the flight experiment by M. Auger in 1925 with a motorless glider from Cherbourg, from which he concludes that had the wings of M. Auger's glider "been unlocked they would have flapped upwards and the aviator would have come down, but if they could have been

unlocked and yet restrained by springs so strong that, until any other force were applied to them they would retain their horizontal position, then it seems credible that their movement would be under the control of the aviator, and, if he knew how to exercise that control to his own advantage, he would actually be flying."

Up to this point Mr. Batten's book is interesting and suggestive, but from this on he devotes himself to the discovery of "a spring or other resilient device of strength and scope of movement" and a lengthy consideration of a something of the wide range of power action of the major muscle in a bird. This leads him to a very extensive series of experiments with silk and other materials employed after the manner of the torse in the Roman catapults and to a chapter on the mathematics of the Catapult Torse. In these experiments he has some assistance from the Testing Department of the British Cotton Industry Research Association, and from the National Physical Laboratory at Teddington, but it need hardly be said that no helping product came of experiments having the object of close imitation of the action of a muscle.

In his further efforts Mr. Batten turned attention to devising an aviation machine, to some extent based on the lines of the model first above mentioned, but with steel springs in an *atterrissage* or frame work in which a man stands and by the use of thigh, leg, arm and back muscles applies the spring power in lieu of the great pectoral muscle of the albatross. As Mr. Batten does now, apparently, feel some misgivings as to the use of the torse, it is not impossible that he might find some inspiration from a consideration of the way in which springs are used in some branches of mechanical engineering to give long range effort of approximately equal strength.

GENERAL NOTE.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH. FOREST PRODUCTS RESEARCH. PROJECT 1—MECHANICAL AND PHYSICAL PROPERTIES OF TIMBERS. TESTS OF SMALL CLEAR SPECIMENS :—One of the chief items in the programme of the Forest Products Research Laboratory is a comprehensive study of the mechanical and physical properties of home-grown and imported timbers. The results of this study will be published from time to time in a series of progress reports. Following the example of the old-established Forest Products Research Laboratories in Canada, India, and the United States of America, it has been decided to publish separately a detailed account of the methods employed, and a definition of the principal technical terms. The present report explains the general purpose of the work, which is to provide data upon which to base comparisons between various species of timber, with reference both to the place of growth of the tree and the position of the specimen in the tree; and to make it possible to determine the effect of exposure and of the various methods of treatment on the mechanical and physical properties of the timber. In this connexion, "clear specimens" are to be taken as meaning straight grained specimens of timber free from defects. The report continues with a detailed account of the methods of mechanical and physical tests. There is an Appendix on formulæ and methods of computing mechanical and physical properties of timber. The report which is copiously illustrated and contains a glossary of technical terms can be obtained, (price 2s. net) from H.M. Stationery Office, Adastral House, Kingsway, London, W.C.2, or through any bookseller.

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All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

FATIGUE PHENOMENA.

WITH SPECIAL REFERENCE TO SINGLE CRYSTALS.

By HERBERT JOHN GOUGH, M.B.E., D.Sc., Ph.D.

(Engineering Department, National Physical Laboratory, Teddington).

III.

(Delivered February, 1928.)

SECTION IV.

FATIGUE STRENGTH OF METALS AS AFFECTED BY THEIR ENVIRONMENT OR CONTACT-SUBSTANCE.

(CORROSION-FATIGUE).

We have seen that the life of a metallic component or specimen may be controlled greatly by variations in (i) the applied stress conditions, and (ii) the temperature at which these stress conditions operate. The test results which have been previously discussed were obtained when the surfaces of the specimens were exposed freely to air. There are many cases in practice where metals are subjected to alternating or fluctuating stresses while in contact, intermittently or permanently, with gases or liquids of various kinds. Comparatively little experimental work has been carried out on the effects of various contact substances on the fatigue strength of metals, but sufficient data have been accumulated to shew that these effects may be very large.

A. HAIGH'S EXPERIMENTS.

Attention was first publicly¹ directed to the subject in 1917 by the work of Professor Haigh^a who described the results of some fatigue tests on typical rolled and extruded brasses, subjected to reversed direct stresses. In addition to the usual endurance tests, additional tests were made on three of the materials when in contact with various corrosive substances. For this purpose a pad of cotton wool wrapped round the specimen was kept soaked with the corrosive substance. Using annealed Muntz Metal, it was found that submitting the specimens to a preliminary immersion in ammonia, followed by washing and drying previous to the fatigue tests, produced no effect on the endurance limit. But other specimens tested while in contact with ammonia had their endurance limit reduced by 10%. It was thus demonstrated experimentally (for the first time) that the effects of fatigue stresses and corrosive influences may be accelerative and produce more harmful effects than either of these effects when acting alone, or when following each other. The endurance limit of a Naval Brass was unaffected by contact with dilute HCl solution, but its value was reduced by 16% by the presence of ammonia. Phosphor Bronze was found to be unaffected by ammonia, dilute HCl, or sea water.

Professor Haigh's results are summarised in Table 1.

(The above endurance tests were carried out on a $1\frac{1}{2}$ million reversals basis only, and S/N curves obtained had not become horizontal at this stage. Hence, too much regard must not be paid to the actual values of the limiting stresses recorded, neither is it certain that the corrosion-fatigue effects had been fully developed.)

Haigh mentions that he had observed that fatigue of mild steels and other metals is accelerated when exposed to corrosion by acids, sal-ammoniac and salt water; in these cases also the endurance limit is reduced appreciably by preliminary corrosion, but the effect is small compared with that of simultaneous corrosion and fatigue. Similar effects have also been observed in practice. Railway axles are particularly liable to corrosion-fatigue, as distinct from corrosion, where exposed to acid effluents from lavatory compartments. In marine practice abnormally rapid fatigue occurs in steel structures immersed

1. NOTE.—The most important feature of Professor Haigh's work, has, to my knowledge never been published, because it represented the solution of a vital problem of national safety during the war and was, necessarily, confidential. But a perusal of Cope Cornford's book on the Paravane is illuminating. After enumerating the difficulties met with in producing a suitable towing wire,—which fractured owing to "tremendous vibration" in sea water—he records that the work of Dr. Haigh was invaluable in solving the problem and resulted in the effective "life" of a 10 ton rope (steel) subjected to a nominal load of 3 tons being increased from 3 hours to 100 hours. The method by which this was done is now probably a matter of general knowledge. It is quite clear, therefore, that Professor Haigh was the pioneer investigator of the combined effects of fatigue and corrosive contact-substance. About ten years afterwards, the subject was re-opened elsewhere, and the results were hailed, in some uninformed quarters, as a *new* development of fatigue phenomena. In order effectually to dispel this illusion, and to draw some attention to the value of Haigh's work, the present note is inserted.

2. Journal Inst. Metals, No. 2, 1917, Vol. 18.

TABLE I.
CORROSION—FATIGUE (HAIGH).

Material.	Tensile Strength (Tons per sq. inch). T.S.	Structure.	Contact Substance.	Limiting Range of Stress (Tons per sq. inch).	Ratios : Limiting A Stresses. T.S.	
Muntz Metal (58% Cu. 41% Zn). Annealed.	26.2	$\alpha + \beta$	Air	± 10.5 (A)	1	0.40
			Air (Specimen immersed in ammonia for 3 hours)	± 10.5 (B)	1	—
			Ammonia ...	± 9.1 (C)	0.90	—
Naval Brass (66% Cu. 32% Zn).	23.2	$\alpha + \text{—}$	Air	± 8.9 (A)	1	0.35
			Ammonia ...	± 7.45 (B)	0.84	—
			Dilute HCl ...	± 8.9 (C)	1	—
Phosphor Bronze.	28.4	α	Air	± 15	1	0.53
			Ammonia ...	± 15	1	—
			Dilute HCl	± 15	1	—
			Sea-water ...	± 15	1	—

in salt water and subjected to vibration. The fracture of marine propeller blades may be due in part to fatigue accelerated by the enhanced corrosive properties of water containing gases in solution. Haigh suggests that such gases are liberated, in the nascent state, by the sudden reduction of pressure produced near the leading edge of the propeller blade.

In view of the practical importance of Haigh's results and the possibilities opened up thereby, it is somewhat surprising to find that eight years elapsed before the subject was investigated further. In 1925 Lehmann commenced a research, at the request of the Aeronautical Research Committee, on the variation of fatigue strength of metals when tested in the presence of different liquids. This work was published in December, 1926. In June of the same year, McAdam published the first of a series of reports on corrosion-fatigue of metals and alloys.

B. LEHMANN'S EXPERIMENTS.³

Two materials, a 0.13% and 0.33% plain carbon steels were employed, and were tested in a vertical machine of the Wöhler type, designed especially for the work. The limiting stresses of these materials were determined when surrounded by hot aqueous solutions of sodium nitrate, sodium chloride and ammonium chloride; also in air *after* the specimens had been pickled in sulphuric acid and then washed in water; also in oil. Control tests were made in hot water and in air at atmospheric temperatures.

The results are summarised in Table 2.

The effects on both steels of a common contact-substance are seen to be, approximately, equal. Thus, pickling in sulphuric acid reduces the limiting

3. Reports & Memoranda Series, No. 1054, October, 1926. (H.M. Stationery Office).

TABLE 2.
CORROSION—FATIGUE (LEHMANN).

Contact Substance.	Limiting Stresses (10 ⁷ Reversals basis).			
	0.13% Carbon Steel.		0.33% Carbon Steel.	
	Tons per sq. inch.	Ratio.	Tons per sq. inch.	Ratio.
(a) Air at 17° C. ...	± 17.2	1.0	± 18.3	1.0
(b) Distilled Water at 96° C. ...	± 16.6*	0.96	± 17.3*	0.95
(c) Air (after preliminary pickling in H ₂ SO ₄) ...	± 15.7	0.91	± 16.8	0.92
(d) NaNO ₃ solution at 17° C. ...	—	—	± 18.4	1.0
(e) NaNO ₃ solution at 96° C. ...	± 15.9**	0.92	± 17.4**	0.95
(f) Lubricating Oil ...	—	—	No affect presumably	—
(g) NaCl solution at 96° C. ...	—	—	± 18.3	1.0
(h) NH ₄ Cl solution at 96° C. ...	—	—	± 18.4	1.0
			± 14.5	0.79

* See notes in text.

stress by 8% to 9%. Hot sodium nitrate solution brings about a reduction of 8% to 5%. Ammonium chloride solution has the maximum effect of 21%. Sodium nitrate, lubricating oil and sodium chloride have no effect on the 0.33% carbon steel. Distilled water at 96°C. effects a reduction of 5% to 6%. Lehmann comments that no signs of corrosion* were apparent after test and ascribes the reduction to a temperature effect. The specimens** tested in contact with hot aqueous solution of NaNO₃ were found to be slightly pitted, the pits increasing in number towards the point of fracture; a specimen run under no load, but in similar contact with the corrosive agent showed a uniform distribution of pits. These facts, shewing the mutually accelerative effects of stress and corrosion, epitomize the outstanding features of corrosion-fatigue as at present understood.

With reference to salt water corrosion, it is perhaps necessary to point out that the effect of a NaCl solution is not necessarily the same as that of sea-water. The composition of sea-water varies widely; the amount of dissolved gases (oxygen or carbon di-oxide) varies between wide limits, and it has been established by many workers that a variation in the amount of these dissolved gases has an important effect on the corrosion produced.

(C) MCADAM'S EXPERIMENTS.

These tests, ⁴, ⁵, ⁶, constitute the most complete set of test-data yet obtained relating to the fatigue of metals in the presence of water (salt and fresh). An interesting feature of the work is that, apparently, this important research was not directed initially at an investigation into corrosion-fatigue, but was

4. Proc. Amer. Soc. Test. Mat., Vol. 26, Pt. 2, 1926.

5. Trans. Amer. Soc. Steel Treat. Sept., 1926.

6. Proc. Amer. Soc. Test. Mat., Pt. 2, 1927.

aimed at the investigation of the shape of the S/N curve at stress ranges which produce fracture after a small number of reversals, *i.e.*, towards the left-hand end of the curve. At such ranges of stress, it is a well-known fact that sufficient heat is sometimes generated within the test piece to make the specimen red hot, or, in many cases, to produce various "temper" colours. McAdam investigated the effects of reducing the temperature of the test piece by such means as lowering the speed of reversal, subjecting the specimen to a stream of water, also altering conductivity effects by using specimens of various shapes. By these means he demonstrated that the form of the S/N curve could be altered considerably. Figure 10 illustrates some experiments on

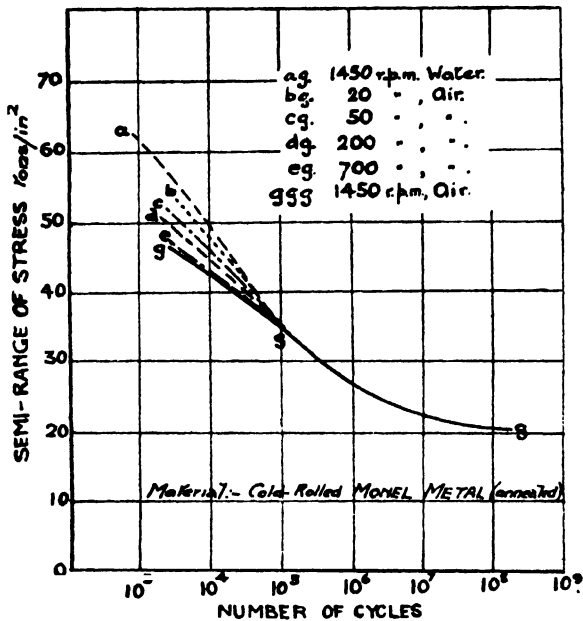


FIG. 10—Influence of Thermal Effects on shape of upper portion of S/N Curve for Monel Metal.

Monel Metal. The curves appear to join at a low number of reversals (10^4) and the effects can be described mainly as "thermal"; the tests have not been carried to sufficiently lengthy endurance to show if the true fatigue range has been affected by the various conditions. The investigation was extended to steel specimens and similar results were obtained. When, however, the tests on the water cooled specimens were carried out at much greater endurance, it became apparent that a "chemical" effect had been introduced which had an unexpected influence on the fatigue-resisting properties of steel. In general, it was found that the S/N curve for water-cooled material at some stage (about 10^8 cycles for 5% nickel steel) begins to descend rapidly below the S/N curve for the same material tested in air. At some stage it began to show signs of

an approach to a horizontal asymptote, indicating that a real endurance limit was developed under the conditions of test. This will be referred to as the "corrosion-fatigue" limit, the term endurance limit being reserved for tests made in air. The investigation was extended to include a wide range of carbon and alloy steels, including "stainless" irons and steels, also some non-ferrous metals. In the majority of the experiments the tests were continued to the stage at which the S/N curve became horizontal (10^8 reversals were commonly employed). Many of the materials were also tested when subjected to a stream of salt water. The fresh water employed was a "well" water containing 21.8 grains of solids per U.S. gallon. The salt water was Severn River water having a saline content of about one-third that of sea-water. In both cases the stream of water was applied so as to sweep the specimen diagonally from end to end and surround the stressed surface entirely by water; all tests were made on a machine of the Wöhler type. Table 3 furnishes some interesting data as to relative effects of the water stream alone and the water stream plus alternating stress. After the stated number of cycles under the stream, the specimens were rubbed with oiled cotton wool.

TABLE 3.

Material.	Tensile Strength ; Tons per sq. inch, T.S.	Limiting Stresses : Tons per Square Inch.					Ratios.				
		Sf	Spc	Sc ₁	Sc ₂	Sc ₃	Sf TS	Spc Sf	Sc ₁ Sf	Sc ₂ Sf	Sc ₃ Sf
0.36% Carbon Steel	Two Heat Treatments.	46.3	22.8	20.1	18.3	15.2	.49	.88	.80	.67	.51
Ditto		35.4	15.2	15.0	14.7	13.0	.43	.99	.97	.85	.80
5% Nickel Steel	Four Heat Treatments.	58.6	27.2	—	—	15.6	.47	—	—	.57	.45
Chromium-Nickel Steel 0.8%Cr.		66.4	32.6	29.4	22.8	19.2	.49	.90	.70	.59	.40
1.56%Ni. 0.38%C.		59.4	29.9	27.2	21.4	17.0	.50	.91	.72	.57	.41
Ditto ditto		51.7	25.0	23.2	21.0	16.5	.50	.90	.81	.64	.46
Ditto ditto		47.3	22.8	20.1	18.3	15.6	.48	.88	.80	.68	.55

Sf. Tested in air to failure.

Spc. 1,500,000 revolutions in water stream free from load : then stressed in air until failure.

Sc₁. 100,000 revolutions in water : then in air till failure.Sc₂. 300,000Sc₃. 1,500,000

"

"

"

"

Figure 11 is a typical diagram of the results obtained.

These data shew clearly that alternating stress plus the water stream has a much greater deterioratory effect than either water or stress alone or water followed by stress. A very surprising result is that the S_{15} values, for all the materials used, lie between the narrow limits of $\pm 11\frac{1}{2}$ and ± 13 tons per sq. inch in spite of the wide variation in tensile strengths ($35\frac{1}{2}$ to $66\frac{1}{2}$ tons per sq. inch). *The effects of varying composition and heat treatments in conferring fatigue resistance have been almost entirely eliminated.*

In Table 4 I have summarised the most significant of Dr. McAdam's test data. The materials investigated include a wide range of carbon and alloy

steels, "stainless" irons and steels, nickel copper alloys ranging from pure nickel to electrolytic copper, aluminium, aluminium-manganese alloy and duralumin. The tensile strengths, endurance limit (in air) and corrosion-fatigue limits (fresh water, and in some cases, salt water) are given.

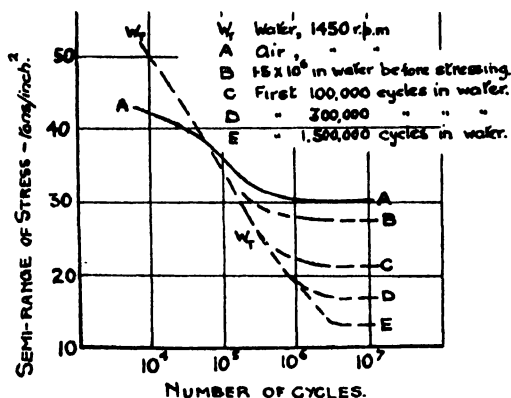


FIG. 11- Typical "corrosion fatigue" S/N curves illustrating the accelerative effects of fatigue stressing and corrosive contact-substance.

The results shown in Table 4, merit some detailed discussion :—

CARBON STEELS.

The carbon contents vary from 0.03% to 1.09% and some steels are tested in two distinct forms of heat treatment. Although tensile strengths up to 50 tons per sq. inch are recorded, a corrosion-fatigue limit of ± 11.2 tons per sq. inch is the maximum developed. It appears that carbon content and heat treatment, although having great influence on the tensile strength and endurance limit, have remarkably little effect on the corrosion-fatigue resistance.

NICKEL STEELS.

The corrosion-fatigue limit of the 3½% nickel steels is slightly higher than that of carbon steels. The corrosion-fatigue limits of the 5% nickel steels, however, are no higher than those of plain carbon steels. The highest value of the corrosion-fatigue limit recorded for the nickel steels is ± 12.9 tons per sq. inch.

STAINLESS IRONS.

The endurance limits of these materials vary widely yet the fresh water corrosion limits all lie between 14 and 15½ tons per sq. inch. As the chromium content of these materials varied but little (11.5% to 15%) it appears probable that the corrosion-fatigue limit is largely controlled by the resistance to corrosion which depends on the chromium content. Variations in carbon content and

TABLE 4.
DR. MCADAM'S DATA.

Material and Approximate Composition.	Investigator's distinguishing mark.	Particulars of Heat Treatment.	Stresses : Tons per Sq. Inch.				Ratios.		
			Tensile Strength.	Endurance Limit : Tested in Air. S	Corrosion-Fatigue Limit : Fresh Water. Sc	Corrosion-Fatigue Limit : Salt Water. Scs	S	Sc	Scs
							TS	S	S
Ferrous Metals and Alloys.									
Ingot Iron, 0.03% Carbon.	EK.17.5	Annealed	18.9	9.4	6.7	—	.49	.71	—
" 0.11% " Carbon Steel "	EK.W.7	Quenched and Drawn	19.6	10.7	8.9	—	.55	.83	—
" 0.14% " " "	B.17.25	Annealed	20.7	11.2	7.1	—	.54	.63	—
" 0.24% " " "	G.W.	Quenched	31.3	16.1	10.3	—	.51	.64	—
" 0.26% " " "	EL.16.5	Annealed	26.4	12.1	7.2	—	.46	.59	—
" 0.36% " " "	EN.4.9	Quenched and Drawn	37.8	17.4	10.3	—	.46	.59	—
" 0.36% " " "	AG.15.5	Annealed	35.3	15.2	11.2	—	.43	.74	—
" 0.36% " " "	AG.W.9	Quenched and Drawn	46.3	23.2	8.5	—	.50	.37	—
" 0.49% " " "	AE.15	Annealed	37.0	15.2	10.3	—	.41	.68	—
" 0.49% " " "	AE.W.10	Quenched and Drawn	49.5	23.6	8.9	—	.48	.38	—
Tool Steel. 1.09% " Carbon	EM.14.75	Annealed	46.2	18.7	10.3	—	.41	.55	—
Nickel-Chromium Steel	BD.W.10	Water Quenched and Drawn at 540°C.	66.4	32.6	12.9*	—	.49	.49	—
1.56% Ni. 0.80% Cr.	BD.W.11.	Ditto 595°C.	59.3	29.9	12.9*	—	.50	.43	—
0.38% C.	BD.W.12	Ditto 650°C.	51.7	25.9	12.1*	—	.50	.47	—
Ditto ditto	BD.W.15	Annealed	47.3	22.8	12.5*	—	.48	.55	—
3.5% Nickel Steel	EJ.14.5	Annealed	41.2	21.8	12.9	—	.53	.59	—
(3.47% Ni. 0.32% C.)	EJ.W.10	Quenched and Drawn	55.7	30.8	11.2	—	.55	.36	—
Ditto ditto	CB.W.10	Quenched and Drawn	57.8	27.2	12.0*	—	.47	.44	—
5% Nickel Steel	CA.14.85	Annealed	54.4	24.6	9.4	—	.45	.38	—
(5.18% Ni. 0.33% C.)	CA.W.11	Quenched and Drawn	59.2	29.4	8.5	—	.5	.29	—
5% Nickel Steel	ZZ	—	48.0	26.6	15.2	—	.55	.57	—
(5.37% Ni. 0.52% C.)	G.O.18	Annealed	27.4	17.4	13.4	—	.64	.77	—
Ditto ditto	GO.W.12	Water Quenched and Drawn	40.3	21.8	13.8	—	.54	.63	—
Stainless Irons	FH.16	Annealed	35.7	18.3	15.2	6.3	.51	.83	.34
12.0% Cr. 0.11% C.	FJ.17	Annealed	43.5	23.2	15.6	—	.53	.67	—
12.2% Cr. 0.08% C.	GN.W.12	Water Quenched and Drawn	40.7	20.3	17.8	5.8	.65	.68	.22
12.2% Cr. 0.08% C.	FI.W.12	Ditto ditto	37.9	22.3	15.6	8.0	.59	.70	.36
11.84% Cr. 0.11% C.	GD	As received	45.8	—	14.7	—	—	—	—
11.54% Cr. 0.33% C.	GA	As received	49.5	—	21.4	—	—	—	—
13.35% Cr. 0.13% C.	FI.17	As received	56.0	22.3	22.3	11.2	.40	1.0	.50
13.76% Cr. 0.09% C.	EV	As received	51.5	24.1	20.1	15.2	.47	.83	.63
15.00% Cr. 0.09% C.	EU	As received	48.5	25.4	22.8	14.3	.53	.90	.56
High Chromium Steel	ES	As received	43.8	22.3	14.3	—	.51	.64	—
(20.5% C. 0.24% C.)	FZ	Normalised	38.1	—	—	6.7	—	—	—
Chromium Nickel Steels	ET.17	Annealed	50.6	—	18.8	8.9	—	—	—
(Stainless Steels)	FK	As received	50.3	25.4	18.3	8.9	.51	.72	.35
17.3% Cr. 8.2% Ni. 0.16% C.	EO.6	Annealed at 315° C.	58.8	22.4	11.2	10.7	.38	.50	.48
17.7 " 25.3 " 0.39 "	EO.14	Annealed at 760° C.	34.2	14.7	10.7	9.8	.43	.73	.67
17.3 " 25.8 " 0.70 "	EP.8	Annealed at 425° C.	56.9	22.8	11.2	12.3	.40	.49	.54
5.4 " 22.9 " 0.24 "	EP.14	Annealed at 760° C.	36.6	16.1	11.2	12.3	.44	.70	.76
6.0 " 22.1 " 0.24 "	E.1	As received	38.4	10.5	9.8†	11.2†	.43	.59	.68
8.4 " 28.2 " 0.45 "	ET.14	Annealed at 760° C.	34.8	13.9	9.8†	11.2†	.40	.70	.80
10.9 " 34.7 " 0.39 "	HE.4	Annealed at 205° C.	27.8	11.2	9.8	10.3†	.40	.87	.92
Non-Ferrous Metals and Alloys.	HE.14	Annealed at 760° C.	21.1	8.1	9.1	8.1	.38	1.0	1.0
Nickel (98.96% pure) Cold Rolled	HF.2.5	Annealed at 120° C.	20.8	7.6	7.6	7.6	.37	1.0	1.0
Ditto ditto	EE.12	Annealed at 650° C.	13.9	4.2	4.2	4.2	.30	1.0	1.0
Monel Metal (70% Ni. 30% Cu.) Cold Rolled	DRB	Hard Temper	9.2	3.8	2.0†	1.3	.41	.53	.34
Nickel Copper Alloy	DRA	Half-Hard Temper	7.1	3.1	—	1.3	.44	—	.42
(48% Ni. 48% Cu.) Cold Rolled	DR	Annealed	5.6	2.7	—	0.9	.48	—	.33
Nickel Copper Alloy	DSB	Hard Temper	13.2	4.9	2.5	1.8	.37	.51	.37
(21% Ni. 78% Cu.) Cold Rolled	DSA	Half Hard Temper	10.6	4.5	2.5	1.8	.42	.55	.40
Copper Electrolytic (99.996% pure) Cold Worked	DS	Annealed	7.5	3.1	1.4	1.8	.41	.45	—
Ditto Hot Rolled	GT	Hard Temper	30.8	7.2	3.5	2.9	.23	.49	.40
Aluminium (99.35% pure)	DU	Annealed	14.9	6.0	3.5	2.9	.40	.58	.48
Ditto ditto									
Aluminium-Manganese Alloy (1.22% Mn.)									
Ditto ditto									
Duralumin									
Duralumin									

* Water stream for first 1,500,000 cycles.

† More tests required to establish this value.

physical properties have very little effect. The salt water corrosion-fatigue limits are very low (± 6.3 to ± 8.0 tons per sq. inch).

CHROMIUM-NICKEL STEELS.

Those steels containing high chromium (16% to 18%) and varying nickel (8% to 25%) contents have a fresh water corrosion-fatigue limit which varies but slightly (± 20 to ± 23 tons per sq. inch). This value is twice as high as for carbon steels and is almost 50% better than for the stainless irons. The steels having a chromium content of 5% to 10% and a high nickel content (23% to 35%) possess inferior corrosion-fatigue limits (± 14 to ± 19). For resistance to fresh water corrosion-fatigue, therefore, high chromium content is evidently more effective than high nickel content. Best resistance to corrosion-fatigue in salt water is obtained with high chromium and high nickel content. A salt water corrosion-fatigue range of ± 15.2 tons per sq. inch was obtained with the 17.7% Cr. 25.3% Ni. steel; this is the highest value yet obtained with any of the metals investigated.

Dr. McAdam examined many physical properties of the materials used to find out if any such property could be found which appeared to exercise any influence in producing an increased corrosion-fatigue resistance. Neither tensile strength, limit of elasticity, ductility, modulus of resistance, nor impact strength, etc., could be correlated with the observed effects. I should like to indicate, however, the practical point of view that it would be considered very satisfactory if the corrosion-fatigue limit of an alloy was to equal its endurance limit (*i.e.*, the corrosive effect to be unimportant.) As we have seen, and as Table 4 also shews, the endurance limit is a fairly constant fraction of the ultimate tensile strength. Hence, it appears that the direction in which to search for a useful material is in that field where composition and heat treatment alike tend to produce marked resistance to corrosion allied with a high tenacity. Of all the materials (ferrous and non-ferrous) investigated the most satisfactory was a stainless steel having the composition 17.7% Cr. 25.3% Ni. 0.39% C., which possessed a tensile strength of 51.5 tons per sq. inch, and corrosion-fatigue limits in fresh and salt water of ± 20.1 and ± 15.2 tons per sq. inch respectively. As the field of investigation is, as yet, largely unexplored, no doubt these figures will be improved upon.

Nickel. (98.96% pure). In spite of increased tensile strength and endurance limit due to cold work, two distinct heat treatments gave a common corrosion-fatigue limit (fresh water) of about ± 11 tons per sq. inch. Salt water reduced this value only slightly to about $10 \pm$ tons per sq. inch.

Monel Metal. This material behaved very similarly to nickel. The corrosion-fatigue limits for fresh and salt water are, respectively, ± 12 and ± 11 tons per sq. inch. The salt water value exceeds that for fresh water.

Nickel-Copper Alloys. The 48% : 48% Ni.Cu. alloy (Cold rolled, also annealed) and the 21% : 78% Ni.Cu. alloy (Cold Rolled) give corrosion-fatigue

values which are practically equal to each other (± 10 to ± 11 tons per sq. inch) and are very nearly the same as for Nickel and Monel Metal. The fully annealed 21/78 alloy *shews no corrosion-fatigue effect at all*, as the value obtained is at least equal to the endurance limit. From the data given more tests are required on the Nickel-Copper alloys, but from the information available, Dr. McAdam deduces that the corrosion-fatigue values of nickel alloys, of compositions varying from the commercially pure nickel down to 21% Ni. and 78% Cu, have a practically constant value. The effects of heat treatment are also eliminated.

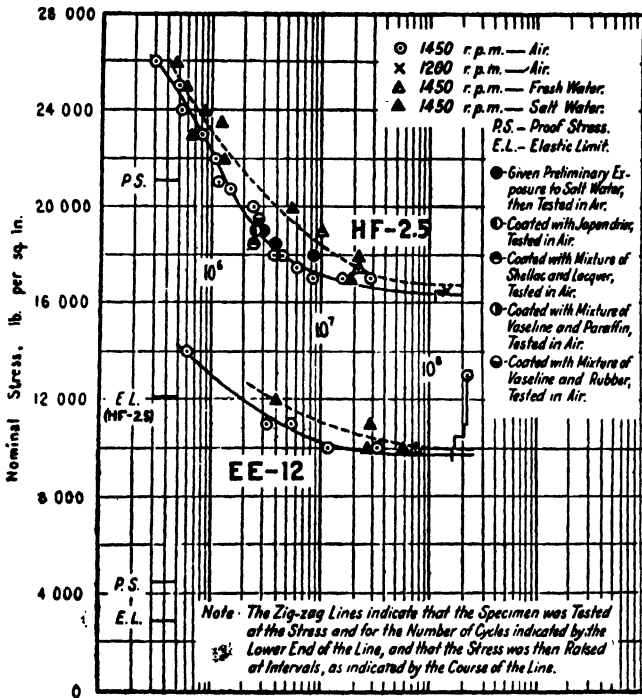


FIG. 12.—Effect of Contact Substance on Electrolytic Copper.
For key to heat-treatment and distinguishing marks see Table 4.

Copper (Figure 12). The cold-worked and hot-rolled metals give values of $\pm 7\frac{1}{2}$ and $\pm 4\frac{1}{4}$ for the endurance limit. *These values are not affected either by fresh or salt water.* This absence of corrosion-fatigue phenomena was not due to lack of chemical action, for the surfaces of the specimens tested in water became heavily coated with films of corrosion products. Neither can it be explained by an unduly low endurance limit; for specimens which were given protective coatings and then tested in air gave similar endurance data. Dr. McAdam suggests that the water streams produced "thermal" effects only. If this is the case, the true endurance limit has a higher value than that obtained

under ordinary test conditions. Such a thermal effect, however, is surprising in view of the high thermal conductivity of copper.

Aluminium and Aluminium-Manganese Alloy. Further test data are required, but the results indicated that marked corrosion effects were present. The salt water values for the pure metal and alloy, respectively, were approximately, ± 1 and $\pm 1\frac{3}{4}$ tons per sq. inch, these values being independent of heat treatment.

Duralumin. This important material was tested in the hard-tempered and fully annealed states. The corrosion-fatigue effects were so marked that these curves and the endurance (air) curves did not meet. The fresh water and salt water values for each material were the same, namely, $\pm 3\frac{1}{2}$ and ± 3 tons per sq. inch respectively. The S/N curves—reproduced in Fig. 13—show another very interesting feature. Whereas the results of the tests made in air are extremely irregular and scattered, yet those relating to fresh or salt water plot very consistently indeed.

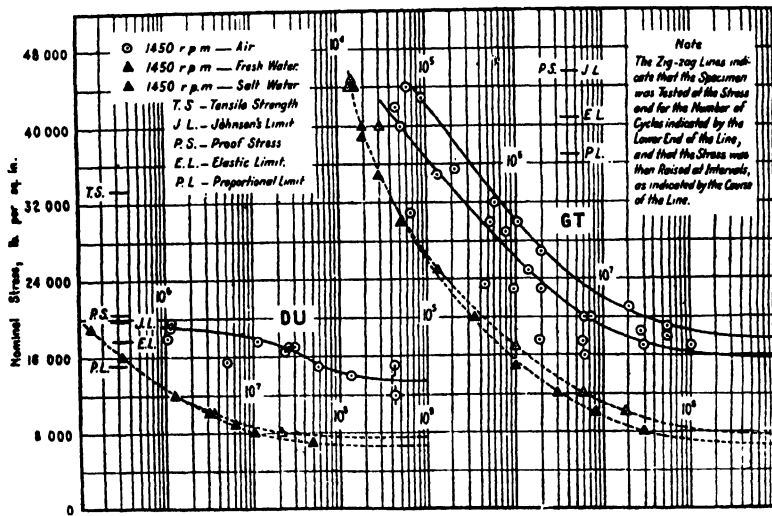


FIG. 13.—Corrosion-fatigue curves for Duralumin (for key to distinguishing marks and heat-treatment see Table 4).

Dr. McAdam examined the surface of some of the specimens which had failed under corrosion-fatigue. It was found that failure, in all cases, was due to cracks which had their origin, or passed through oxide patches surrounding non-metallic inclusions; Figure 14 is a typical photomicrograph (100 X), showing a failure in a typical specimen. There appears to be little doubt that local stress concentrations must be set up at these points. Similar rusty patches, however, were observed on those specimens which were subjected to 100,000 reversals only under water prior to a test in air; these preliminary treatments, as we have seen, did not cause a very great reduction in the endur-

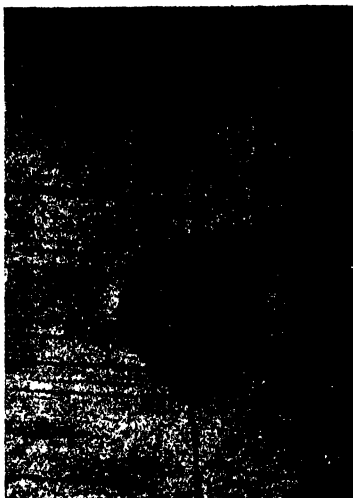


FIG. 14—Corrosion-fatigue cracks and oxide patch ($\times 100$).

ance limit. Therefore, the corrosion-fatigue effect is not due merely to local roughness of surface caused by corrosion, but to the combined effects of corrosion and alternating stress. A marked resemblance is at once seen between corrosion-fatigue phenomena and the well-known effects of combined static strain or internal stress in the presence of corrosive media.⁷ In both these cases, the action is probably of a molecular nature, the process of rupture of atomic bonds by chemical action being greatly assisted when these bonds are in a state of static strain or subjected to a range of strain. Indeed, it appears to the writer that a certain limiting strain involving the value of the elastic modulus together with the action of the applied corrosive agent will most probably be associated with a corrosive-fatigue limit of a material. This view receives support from McAdam's results which shew that the corrosion-fatigue limit suffers only small variations over groups of similar materials. But it is unwise to attempt theorising, except in a very guarded way, until the experimental side of the subject has been more fully explored. Experiments conducted at various temperatures and at various speeds are urgently required. McAdam examined a number of steel specimens to determine the path of the cracks. When the crack lay between two widely separated inclusions, it sometimes followed the intercrystalline boundaries for a short distance, but the fractures were mainly trans-crystalline.

D. R. R. MOORE'S EXPERIMENTS.

Some endurance tests on metals previously subjected to a salt spray (20% NaCl) have been reported by Moore.⁸ The materials used included a chromium

7. See "The Failure of Metals under Internal & Prolonged Stress," General discussion organised by Faraday Society on April 6th, 1921.

8. Proc. Amer. Soc. Test. Mat., Vol. 26, Pt. 2, 1926; also Vol. 28, Pt. 2, 1927.

TABLE 5.
R. R. MOORE'S EXPERIMENTS.

Material.	Preliminary Exposure to Salt Spray.	Tensile Strength ; Tons per Sq. Inch. A.	Endurance Limits ; Tons per sq. inch.		Ratios.	
			No pre-liminary corrosion. B.	After pre-liminary corrosion. C.	$\frac{B}{A}$	$\frac{C}{B}$
Chromium-Vanadium Steel.	40 days Continuously.	34.0	15.4	12.0	0.45	0.78
Duralumin	5 days intermittently.	31.0	8.0	5.4	0.26	0.67
	10 days intermittently.			4.9		0.61

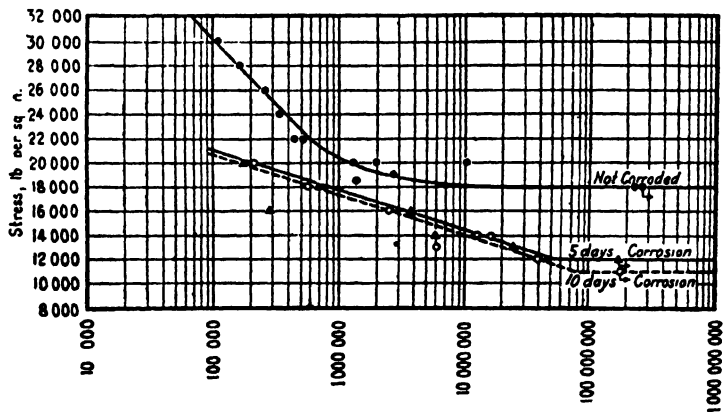


FIG. 15—Effect of Corrosion on Duralumin Tubes (see Table 5).

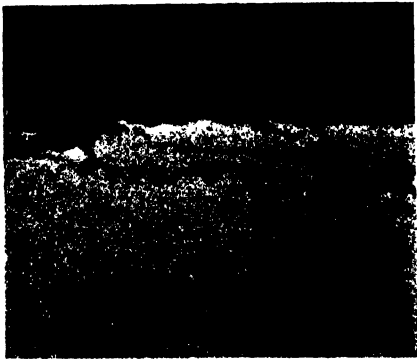


FIG. 16—Photomicrograph of section of corroded duralumin tube showing inter-crystalline cracking (see Table 5).

vanadium steel (1.07% Cr. 0.18% Va.) and duralumin (in the form of tube). The results are summarised in Table 5.

Obviously, the preliminary exposure to salt water corrosion does not have so great an effect as the corrosion fatigue effects observed by McAdam. Fig. 15 shews the S/N curves recorded. Figure 16 shews a photomicrograph representative of the surface of the corroded duralumin. The corrosive action is of the inter-crystalline type, extending to a depth of 0.0004 inches only below the surface.

The above experiments, in the opinion of the writer, amply demonstrate the importance of the effect which the environment may exert on the fatigue resistance of metals. Together with stress effects, temperature effects and surface form effects, the contact-substance effect must now be regarded as one of the main aspects of fatigue requiring study, and is certain to receive much attention in the future. When corrosion-fatigue is likely to occur in practice, adequate protection by suitable means must be provided. It is interesting to note that the various workers on corrosion-fatigue have chosen as their "standard of performance" the fatigue strength when tested in air. This is, of course, an important practical standard. From a fundamental point of view, however, it appears to be worth while endeavouring to obtain some fatigue data from specimens tested either in a vacuum or in an atmosphere of inert gas. Finally— one word of caution. The term "corrosion-fatigue limit," as used above, denotes simply and solely the limiting range of stress of a material under the *precise conditions of test used* in the experiments. It does *not* denote a physical property of the material as the most important condition—the *rate of supply of oxygen to the stressed surface*—was not determined (although this rate was probably maintained *constant* over the experiments, judging by the regularity of the plotted results.) Should this rate of supply be varied, large variations in the results would be expected. Again, cycles of direct stress would almost certainly produce results differing from those obtained in Wöhler tests, even though all the other conditions of test were precisely similar. Hence, extreme caution must be taken in applying any such test data to actual design. Knowledge of the fundamental aspects of corrosion—with or without superimposed stress—is extremely limited at the present time, although research in these directions is being actively pursued.

SECTION V.

FATIGUE RESISTANCE OF METALS TO IMPACT (IMPACT-FATIGUE).

The resistance of metals to repeated impacts has attracted the attention of a few investigators only. This is probably due to the fact that the fundamental aspects of the subject were so thoroughly investigated by Stanton and Bairstow,*

9. Proc. Inst. Mech. Engrs., Nov. 1908.

in 1908, that impact-fatigue phenomena and their relation to other forms of test were established on a sound basis. It will be sufficient to discuss briefly their experiments on repeated impact bending in which notched bars were employed, although the resistance of metals to direct impacts were also investigated. In the machine¹⁰ used, the specimen, in the form of a simply supported beam, with a vee notch at mid-span is subjected to repeated impacts by means of a weight (whose mass can be varied) raised to and released from a pre-determined height by a mechanically operated cam. After each blow, the specimen is rotated through half a revolution, the blows thus being applied on alternate sides of the specimen. The working speed of the machine was 100 blows per minute. Typical energy of blow-endurance curves are illustrated in the original paper; they reproduce the characteristics of the familiar S/N curves of fatigue under alternating stresses. A series of wrought irons, mild and medium carbon steels were investigated. Figure 17 summarizes, in a striking manner, the varying characteristics of the whole series of metals as the number of blows to cause fracture varies from one to one hundred thousand blows in the series:—1, 10, 100, 250, 500, 750, 1,000, 2,000, 10,000 and 100,000 blows; the curves are plotted on a carbon content base. Although Stanton and Bairstow did not determine the true fatigue ranges (Wöhler tests) of these materials, such complete particulars of the tensile strength, composition and treatment, are given in the original paper that the Wöhler range (un-notched specimens) can be estimated with fair precision from data at the N.P.L. I have made these estimations and the relative values are inserted in the first and last diagrams as dotted curves.

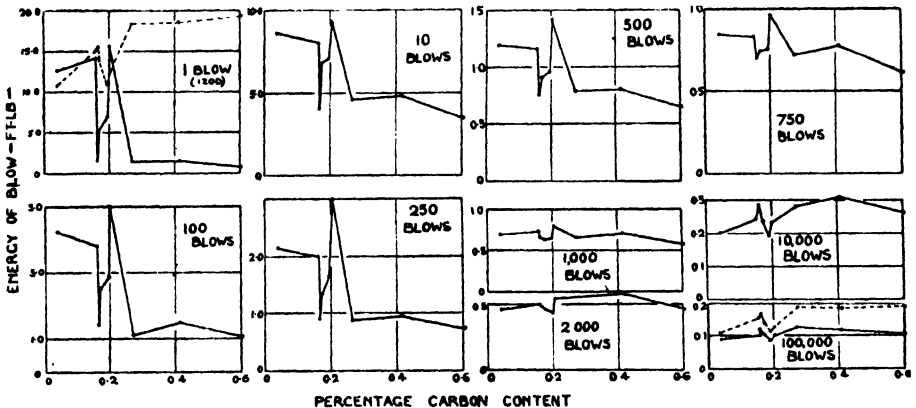


FIG. 17.—Results of Stanton and Bairstow's Impact-Fatigue Tests on Steel.

It is apparent (from the first curve) that the energies to fracture under one blow bear no relation to the true fatigue ranges, and the characteristics of the two curves are practically reversed. This is also true for the 10, 100, 250, 500,

10. The Stanton Machine in a slightly modified form is made on a commercial basis by The Cambridge Instrument Co., Ltd., and is used in many research laboratories and works.

and even 750 blow curves, although a subtle change is taking place in the general form of the curves, the peaks becoming smoothed out. The elastic resistances, which were inappreciable in resisting a heavy blow, become of increasing importance as the number of blows to fracture increases. At 10,000 blows, the characteristics of the one-blow curve are practically reversed, a peak in one curve corresponding to a depression in the other. After 100,000 blows, the energy curve and the true limiting range curve, are almost precisely similar. That they are not identical in shape is probably due to two causes (a) the "notch" effects on the various materials are not exactly the same, and (b) the limiting energy of blow (insufficient to cause fracture after an indefinitely great number of impacts) was not fully disclosed at 100,000 blows. As Stanton & Bairstow point out, the *limiting proof resilience* of materials subjected to impact stresses will be proportional to $\frac{f^2}{E}$ where f is the true endurance limit and E is the value for Young's Modulus for the material. They shew that this condition is closely realised for a carbon steel and an aluminium alloy which metals possess widely different values of E .

The practical importance of the results of this research cannot be over-emphasized. Machine components are mostly subjected to shocks in addition to the usual type of fatigue stresses; and such members often contain discontinuities of some kind (screw threads, keyways, etc.). Stanton and Bairstow's work shews that if the superimposed shocks are of a relatively *small* order, then the design should be based chiefly on the true fatigue properties of the materials. On the other hand, should occasional or frequent *heavy* shocks be anticipated, the notched bar value of the material must also be taken into consideration. If materials possessing both these properties can be employed, so much the better, but sometimes, in practice, this cannot be achieved and due consideration must be given to both aspects of the problem.

McAdam¹¹ has determined the impact endurance properties of some carbon and alloy steels. The tests included single blow notched bar tests, impact-bending endurance tests on notched bars and the usual Wöhler tests on un-notched bars. The impact-bending machine is based on Stanton's machine; the specimen, however, is continuously rotated through 90° only between successive blows. The impact endurance tests were extended to several million blows. The usual characteristic form of energy-blow curves were obtained. The results of the tests are summarised in Table 1.

It is clear that no relation exists between the ordinary impact and the impact-fatigue values for these materials; on the other hand, the ratio of the endurance limit to the impact-fatigue figure for all these steels varies but little, thus confirming the basic conclusions of the pioneer work of Stanton and Bairstow.

TABLE 1.

Materials (Steels).	Impact Tests.				Ratios (Relative).			
	Tensile Strength ; Tons per Sq. Inch.	Energy to fracture : Single Blow; Ft. Lbs. (Charpy Test). (2)	Limiting energy to fracture 10 ⁷ blows; Ft. Lbs. (Impact Fatigue Test). (3)	Endurance Limit 10" Reversals (Wöhler Test) : Tons per Sq. Inch. (4)				
					(4) (1)	(3) (2)	(4) (2)	(4) (3)
Silicon-Manganese	70.4	3.69	0.098	27.7	0.39	1.00	1.00	1.00
Chromium-Vanadium	65.5	13.35	0.110	29.9	0.46	0.32	0.30	0.97
Chromium-Molybdenum	63.3	29.12	0.100	30.1	0.47	0.13	0.14	1.07
Nickel-Molybdenum	50.5	22.45	0.100	25.4	0.43	0.17	0.14	0.91
Nickel-Molybdenum	46.7	10.32	0.085	20.8	0.45	0.31	0.27	0.87
Chromium-Molybdenum	41.2	24.45	0.075	21.0	0.51	0.12	0.11	0.99
Plain Carbon	31.2	21.0	0.048	13.4	0.43	0.01	0.09	0.99

The reader is also referred to a paper by R. R. Moore¹² containing the results of impact-fatigue tests on a series of non-ferrous metals which included some light alloys.

NOTES ON BOOKS.

THE GROWTH OF THE ENGLISH HOUSE. By J. A. Gotch. London: B. T. Batsford, Ltd. 12s. 6d.

A celebrated philosopher of antiquity was content to reside in a tub. Philosophers of any epoch should be happy in a small cottage or house, but most of them would not suggest that a larger house is reasonably undesirable. Indeed, houses are in a sense the core of civilisation. Architecture is the first of the arts in logical order, and painting, sculpture, and the minor arts are generally thought of in relation to a building. Churches and public buildings have of course taken much art under their wings, but it is the house, the abode of an individual, of a line of individuals, that is the true home also of the arts and graces that are the embodiment and expression of culture.

We need not here compare our English culture with that of foreign countries. But one general observation may perhaps be made without odium being incurred. A certain kind and degree of civilisation was very evenly spread over this country, and it lasted relatively a long time. It has lasted till the present day. A number of our manors and great houses are still not merely inhabited by their owners during the summer months *en villégiature*, but remain an organic part of the social scheme. They are dotted over the counties, the local pillars of church and state, and in them live the local disseminators of a theoretical and practical view of life. The history of these houses is of no less absorbing interest than the history of their owners or of the ideas which have governed their owners during the last few hundred years.

Mr. Gotch is an excellent historian of the English house, which he traces from its origins as a Norman Keep down to its fairly recent stages of development.

The Norman Keeps, belonging to great lords, had firmness, but not commodity ; whatever they may have been like a thousand years ago, they have in process of time acquired delight. See the illustration of Peak Castle. By the eighteenth century quite obscure commoners were able to live in houses that were firm, commodious and delightful. Why did the nineteenth century builders forget the lessons of the past and build houses that were firm, sometimes, certainly not commodious, and that no millenary period of weathering and erosion could render delightful ? Too many twentieth century architects believe that anything " useful " must be beautiful. They also have an idea that it is worth exploiting the technical potentialities of any and every material which may happen to lend itself to construction.

From the Keep Mr. Gotch passes on to the Hall, at first a hardly less barbarous interior, though as an exterior somewhat less suggestive of a world in which human life was nasty, brutish and short. It is interesting to observe at this and much later stages how timidly people still refrained from increasing the size of their ground floor windows.

It was rather a hard struggle forward through the middle ages to the time when the Renaissance enabled men to benefit by the experience of competent and sophisticated builders of the past. The medieval manors were not only not symmetrical, but haphazard and wasteful. There followed, in England as in France, a transitional stage of architecture when ancient and modern elements were mixed. Warkworth Castle in Northumberland is a good example of the type of house in question. Again, in England as in France, the first signs of Italian Renaissance influence are to be found in the ornamentation rather than in the structure of houses. Often quaintness—scarcely a good quality—was the result ; beauty occasionally. This period of assimilation may be said to date from the building of Christ Church by Wolsey and to last till the rise of Inigo Jones. Torrigiano's tomb of Henry VII at Westminster was the first notable piece of Renaissance workmanship in England.

The houses that were often quaint and sometimes beautiful included in their number some of the most stupendously large, and therefore, in a way, impressive, in the land. They included Audley End and Hatfield, Longleat and Longfort. Out of this more or less agreeable chaos Inigo Jones was to guide his art.

Jones was born in 1573, and his career opened in 1604, just before Hatfield was built. In 1615 he became Surveyor-General of the Works, and in 1619 submitted his scheme for the rebuilding of Whitehall. Sir Walter Armstrong has said that " Jones's second Whitehall is the most astonishing creation by a single mind that the history of architecture has to show." " Astonishing " is itself an inadequate epithet. Mr. Gotch says that the " main cause of the change " in the nature of English architecture at this time " is to be found in the pursuit of the Italian ideal." This again is a little inadequate : he might have said the " pursuit of the ideal with the help of the Italian idealists." With Jones " started the personal architecture of the designer who controlled the decoration throughout, as opposed to the impersonal architecture of the independent craftsmen who preceded him."

To-day we have examples of " impersonal architecture " which may lead anyone to suppose that nothing good could ever have been produced by such a system. This is of course far from the truth ; but our " impersonal " jerry-building is disgraceful.

Wren was more a builder of churches than of houses ; his influence on domestic architecture was anyhow not in proportion to his general importance. The brothers Adam humanised and urbanised the house. I do not know what is going to happen to the Adelphi, but it is a satisfaction to be sure that at least the Royal Society of Arts has the freehold of its admirable premises in John Street. P.B.

CREATINE AND CREATININE. By Andrew Hunter, M.A., M.B., F.R.S.Can.
London: Longmans, Green & Co., Ltd. 14s. net.

The mutually convertible substances creatine and creatinine, while it seems probable that they are not produced by the invertebrata, are present in all vertebrate animals, and also in certain of the more highly organized forms of plant life. Though their chemical constitution has been known for sixty years or more, there is still considerable doubt, both as to their function, if any, and also as to their origin in the living organism. In this detailed study, which forms a valuable addition to a well-known series of monographs on Biochemistry, the whole mass of known facts, together with a number of the speculations which have emerged, are collected and lucidly presented.

Professor Hunter argues against the supposition that creatine is a mere product of catabolism in muscle or any other tissue, and is inclined to conclude that it performs a definite function in connexion with "that capacity for rapid and powerful contraction, which is the most important property of striated muscle." As regards origin, he rejects the usual view that creatine arises almost exclusively in the muscles, holding that "the actual site of creatine formation is as uncertain as its chemical mechanism," that is to say, as its method of formation in the organism; there is no uncertainty as to how the substance can be synthesized in the laboratory.

The general arrangement of the book is well suited to the subject. The purely chemical aspect, which is concerned for the most part with easily provable facts, is first dealt with in three chapters which really form a division of their own. Subsequently, the physiological problem is investigated in the usual manner, the biological distribution of the substances is described, together with the data as to their output and excretion, and a mass of evidence as to their physiological significance is reviewed. Pathological aspects are, on the whole, omitted, save in so far as they seem to contribute to the solution of the purely physiological problem.

The bibliography, in which approximately one thousand original papers are noted, is a model of excellence, and readers will be grateful to the author for having based his work on the original literature alone, thereby having been able, as he says, "to detect and correct more than one error of fact or mis-statement of opinion that has become current in books of reference."

GENERAL NOTE.

INTERNATIONAL CONGRESS FOR ART EDUCATION, PRAGUE.—The British exhibit of work sent to this Congress, which was held in Prague last month, is now on view in the North Court of the Victoria and Albert Museum, and will remain there until the 29th inst. A descriptive report on the Congress will be given on the 22nd inst. at 3 p.m. in the Lecture Theatre of the Museum. The work illustrates the teaching of design in relation to handicraft in various kinds of schools and colleges and is fairly representative.

EXHIBITION OF ENGRAVINGS BY FRANCESCO BARTOLOZZI.—The second centenary of the birth of the engraver, Francesco Bartolozzi, is being celebrated this year at Florence by an exhibition of his engravings in the Print Room of the Uffizi Gallery. Francesco Bartolozzi was born in Florence on September 25th, 1728. He was placed by his father in the Academy of Arts at Florence, then under the direction of

an Englishman, Ignatius Hugford, and was later apprenticed at Venice to the engraver, Joseph Wagner. At the end of this training, when he was already a brilliant engraver, he met in Italy, Dalton, the librarian of King George III., who was collecting works of art for his royal patron, and offered to Francesco the post of engraver to His Majesty : the offer was accepted, and Bartolozzi came to London in the year 1764. His first important commission was his magnificent series of line engravings from Guercino's original drawings in the Royal Collection at Windsor. His contract with Dalton was for three years, and when it ended there was a strong competition between Dalton and the publisher Boydell for his services : the latter's offer was preferred as leaving the artist more free in his work. The beautiful print of the *Virgin and Child* (called *The Silence*) after Annibale Caracci belongs to his time with Dalton, and the no less fine oval of *Clytie* was engraved for Boydell a little later—two prints which are of first interest and value to the collector. But at this time stipple engraving was introduced into England, and at once created such a public interest and demand that Bartolozzi was obliged to take pupils and assistants. At the foundation of the Royal Academy of Arts in 1769 he was one of the earliest members, and his position in England was a very high one. He had brought with him from Italy her classic tradition, and had joined with it the fine and strong portrait work of our English school in that period ; in this connection his engraved portraits of Lord Thurlow, Lord Heathfield and the Earl of Mansfield are of special interest, and from the designs of Angelica Kauffman and his intimate friend Cipriani he engraved many charming classic subjects.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH. FOREST PRODUCTS RESEARCH. PROJECT I: PROGRESS REPORT I. TESTS OF SOME HOME-GROWN TIMBERS IN THEIR GREEN CONDITION.—One of the investigations being carried out at the Forest Products Research Laboratory of the Department of Scientific and Industrial Research is a study of the mechanical and physical properties of timbers. The means by which the comparison between different timbers is carried out has been published in Project 1. Shortly, the aim of the investigation is to provide necessary information to assist the user in selecting the most economical species of timber for any particular purpose by means of tests of small clear specimens of timber. Such tests, though not yielding figures suitable for use as a basis for design, nevertheless indicate the relative merits of the timbers, so that a timber which has the highest qualities to resist any type of mechanical strain may be chosen from those which are offered for the purpose. Further, the results of these tests on home-grown timbers indicate to the forester which are the most suitable species of timber to be grown in this country, taking into consideration the rate of growth and the resultant strength of the timber. The present Progress Report is the first of a series of reports giving the results of the investigation and deals with tests on the timber, in its green condition, of Home-grown Ash, Douglas Fir, E. Larch, Corsican Pine and Scots Pine. The report describes briefly, with illustrations, the eight mechanical tests to which the timbers were subjected. It includes a table showing the locality and the general character of the specimen trees selected for each species, and a statement of the number of tests made and the conclusions drawn as to the relative merits of the different timbers for various purposes. In an appendix the numerous test results obtained by species are completely expressed in tabular form and, for easy comparison, future results will be set out in the same manner. The table is supported by a diagrammatic representation of the relative properties of the various species. The Report may be obtained (price 9d. net) from H.M. Stationery Office, Adastral House, Kingsway, London, W.C.2, or through any bookseller.

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*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C. (2.)*

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

FATIGUE PHENOMENA, WITH SPECIAL REFERENCE TO SINGLE CRYSTALS.

By HERBERT JOHN GOUGH, M.B.E., D.Sc., Ph.D.

(Engineering Department, National Physical Laboratory, Teddington).

IV.

(Delivered February, 1928.)

SECTION VI.

CYCLICAL STRESS-STRAIN RELATIONS.

The first accurate study¹³ of the stress-strain relations obtaining during a fatigue test was made by Bauschinger, and first published in 1881. He used a machine in which specimens were subjected to cycles of repeated tensile stresses. By means of a mirror extensometer he ascertained the initial elastic limit of the material and the elastic limit acquired by repetitions of stress. He found that when the acquired elastic limits were equal to or greater than the maximum stress of the cycle, a very large number of repetitions was required to fracture the specimen, while, if the acquired elastic limit was less than the maximum stress of the cycle, the specimen broke with a few repetitions only. Bairstow in the following words has summarised concisely the theory which Bauschinger enunciated as representing the results of these experiments:—

13. For an excellent summary of these tests see Rept. Brit. Assoc. 1887, p. 429.

"The superior limit of elasticity can be raised or lowered by cyclical variations of stress, and at the same time the inferior limit of elasticity will be raised or lowered by a definite, but not necessarily the same, amount. The range of stress between the two elastic limits has, therefore, a value which depends only on the material and the stress at the inferior limit of elasticity. This elastic range of stress is the same in magnitude as the maximum range of stress which can be repeatedly applied to a bar without causing fracture, no matter how great the number of repetitions."¹⁴ Bairstow's research, published in 1910,¹⁵ in which he investigated experimentally this theory of the "natural" elastic limits, is one of the most important and instructive studies of fatigue phenomena ever recorded. Bairstow employed cycles of direct stress, of which the range and mean stress could be adjusted to predetermined values. By means of a mirror extensometer, changes in length of the specimen, at various stages of the test, were measured, also the stress-strain relations obtaining in individual cycles of stress. Time will permit only of reference to the results of two typical experiments of Bairstow's.

(i) REVERSED STRESS TESTS (AXLE STEEL).

The stress-strain relations for repetitions of various cycles of reversed stress (mean stress zero) were studied throughout the history of each specimen. The term "cyclical permanent set" was given to the small difference of length of the specimen while loading and unloading at the mean stress of the cycle (zero stress in this case). The first stress range applied was ± 14.1 tons per sq. inch and the first loading shewed the material to be sensibly elastic. Under repetitions of the same range of stress, the linear stress-strain relation developed into a loop, termed a "hysteresis" loop from analogy. The variations of the width of the loop with repetitions of any one range of stress, also with various ranges, were recorded. At higher ranges of stress it was found that the initial width of the loop diminished with repetitions during the early stages of the test. Bairstow mentions that no appreciable permanent extension of the test piece resulted from cycles of *reversed* stresses.

(ii) FLUCTUATING TENSILE STRESSES. (AXLE STEEL).

Fig. 18 illustrates the extremely interesting case of fluctuating tensile stresses in which the maximum stress of the cycle was maintained at a constant value (34.4 tons per sq. inch), and variations in the applied range produced by reducing the value of the inferior, or lower, limit of stress. In this case, the specimen suffered considerable permanent extensions which are recorded on the diagram. Under the first range of stress the specimen acquired a state

14. NOTE.—It is interesting to recall that this theorem is almost precisely identical, even to the terms employed, with that enunciated by James Thomson in 1848. (See Section on "Early History.")

15. Phil. Trans. Roy. Soc. A., Vol. 210, 1910.

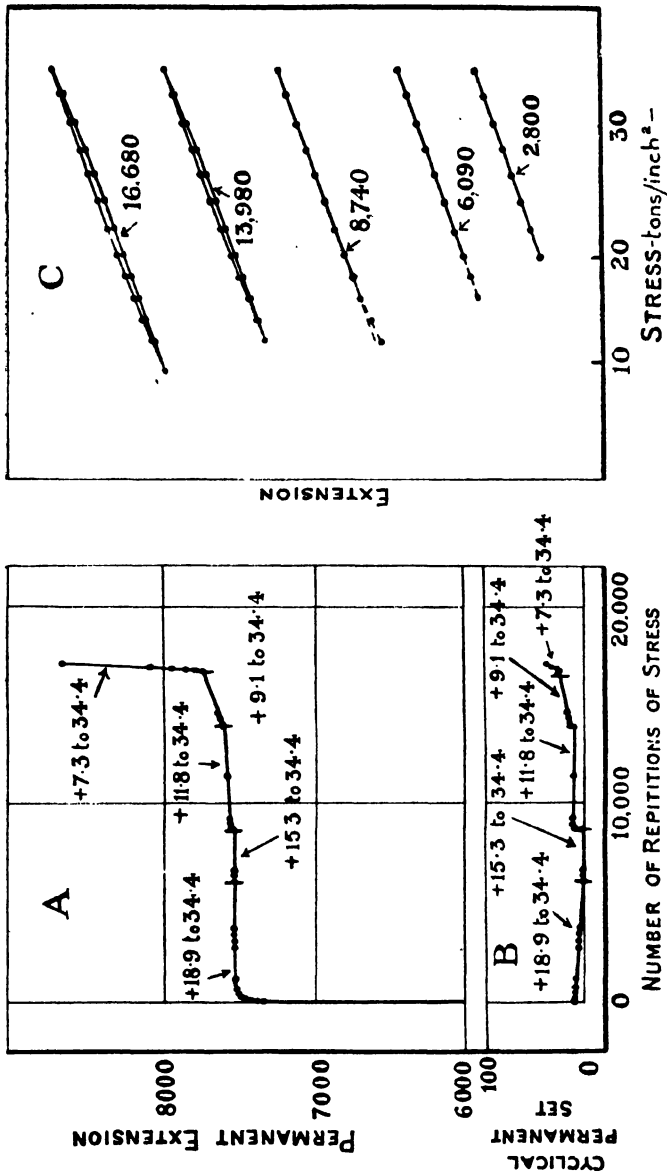


FIG. 18. Stress-Strain Relations exhibited by Steel subjected to Fluctuating Tensile Stresses.

of elasticity after an initial yield accompanied by hysteresis effects. This range was assumed to be a safe range. Reducing the lower stress to 15.3 tons per sq. inch did not produce either hysteresis or further permanent deformation. The interesting point was thus made that the total deformation due to *safe* ranges of stress depends only on the maximum stress of the cycle; this is illustrated completely in a diagram¹⁶ which represents a summary of Bairstow's

16. See original publication.

experiments on axle steel. Thus, when the superior stress of the cycle was less than the static yield point, the total extension under cycles of stress was equal to or greater than that due to static loading. For higher values of the superior limit, the total extension was the same for both types of loading (static and fatigue).

Other investigations, also carried out at the National Physical Laboratory, of a similar nature—of Hankins¹⁷ on nickel, of Gough & Hanson¹⁸ on Armco Iron, and Gough¹⁹ on copper—when considered in conjunction with Bairstow's results, cover the three general cases: (a) Range of Primitive elastic limits greater than the safe range of reversed stress, (b) safe range of reversed stresses exceeding the range of the primitive yield points, and (c) the metal possessing no primitive elasticity, although exhibiting a clearly-defined range of stress. As a result, the cyclic stress-strain relationships during a fatigue test can be summarised, briefly, in three distinct stages, as follows:—During the first stage of the test relatively large unclosed loops are observed whose widths tend to diminish with subsequent cycles; alternatively, a loop is formed and attains a certain width. During the second stage (which may extend over millions of cycles) the loop may maintain a constant width, or may slowly

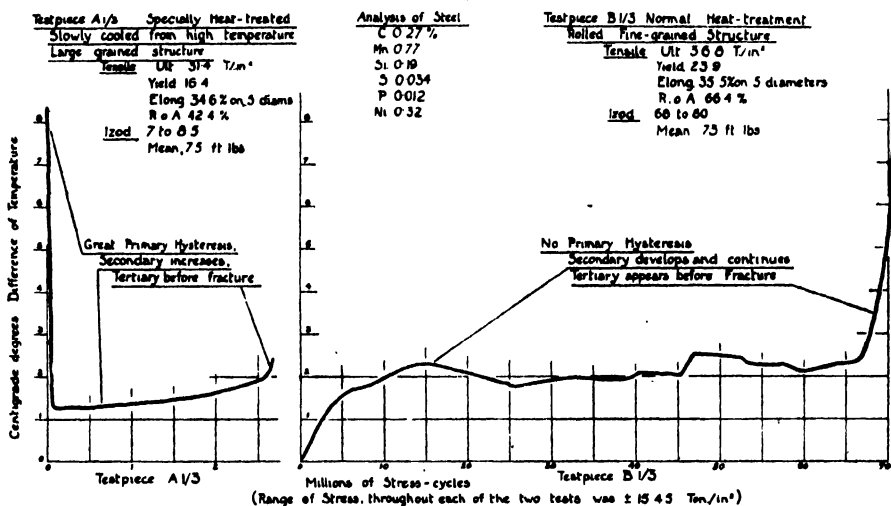


FIG. 19. Hysteresis, as revealed by heating effects, during lengthy fatigue tests.

increase or decrease. During the third stage of the test the rate of increase of permanent set and of cyclical permanent set usually increases and fracture results. The first and second stages are common both to safe and unsafe ranges of stress; the third stage is almost certainly connected with the propagation of small fatigue cracks through the specimen and is associated with

17. No. 789, Reports & Mem. Series, Aero. Res. Ctee, Nov. 1921.

18. Proc. Roy. Soc. A., 104, 1923.

19. Engineering, September 8th, 1922.

unsafe ranges of stress. As we have seen, these phenomena are shewn clearly by plotting the records of extensometer tests. As the area of a hysteresis loop represents work performed on the specimen by the applied straining forces, and as most of this work re-appears in the form of heat, a measure of the hysteresis effects operating through a continuous fatigue test may be obtained by the use of thermo-couples, etc. The method has been used by a number of investigators,²⁰ but has received very detailed attention, of recent years, by Haigh²¹ who employs a multiple thermo-couple for use with the Haigh Machine. Fig. 19 shows typical results obtained in this manner. They reproduce exactly the hysteretic phenomena deduced from extensometer tests exhibiting the same three general stages.

One of the most interesting of fatigue phenomena is the fact now regarded as definitely established, that a metal subjected to repetitions of a safe range of stress finally achieves a state in which, although no further permanent set will appear, strain hysteresis is present, and will persist indefinitely without causing fracture of the material. The form of the stress-strain loop has been accurately determined by various investigators,^{14, 18, 19, 20, 21, 22, 23}, with complete agreement and is shewn in Figure 20. The term "Elastic hysteresis"—probably first used by Hopkinson & Williams²⁴—is employed to denote such a cyclic state. The writer has found such a state to persist unchanged in Armco Iron for 100,000,000 reversals of stress. It has been said that strain hysteresis is an effect peculiar to crystalline aggregates, having its origin at crystal boundaries. To examine this possibility, the writer and his colleagues²⁵ made a very carefully conducted test on a large single crystal of aluminium (diameter $\frac{1}{2}$ -inch, length 7-inches). The specimen was subjected to cycles of repeated tensile stresses, an extensometer of very great precision being employed. Following the usual plastic strains (which were observed at the lowest stress range employed, 0.07 ton per sq. inch, Fig. 20 (a)), the metal gradually attained a cyclic state involving strain hysteresis without further permanent set (Fig. 20 (b)). The hysteresis loop was of precisely the same shape as exhibited by crystalline aggregates. Fig. 20 (c) shows the stress-strain relations exhibited by the crystal when in the cyclic state. Hence it must now be accepted that strain hysteresis is a property exhibited by crystalline matter and not to be ascribed simply and solely to boundary effects in aggregates. Rowett²¹ carried out tests which shewed that the dissipation of energy per cycle due to hysteresis was the same at high as at low speeds, and is a function of the value of the stress range. Hence the cause of hysteresis in metals is not analagous to the viscosity of fluids. Some recent work by Kimball

20. See "Fatigue of Metals," Gough, Chapter 6, for an account of these researches.

21. "Hysteresis in Relation to Fatigue": General Discussion on Cohesion and Related Problems, November 23rd, 1927.

22. Rowett, *Proc. Roy. Soc.* Vol. LXXXIX, 1913, p.528.

23. Gough, Hanson & Wright, *Phil. Trans. A.* 226, 1925.

24. *Proc. Roy. Soc. A.*, Vol. 87, p.502, 1912.

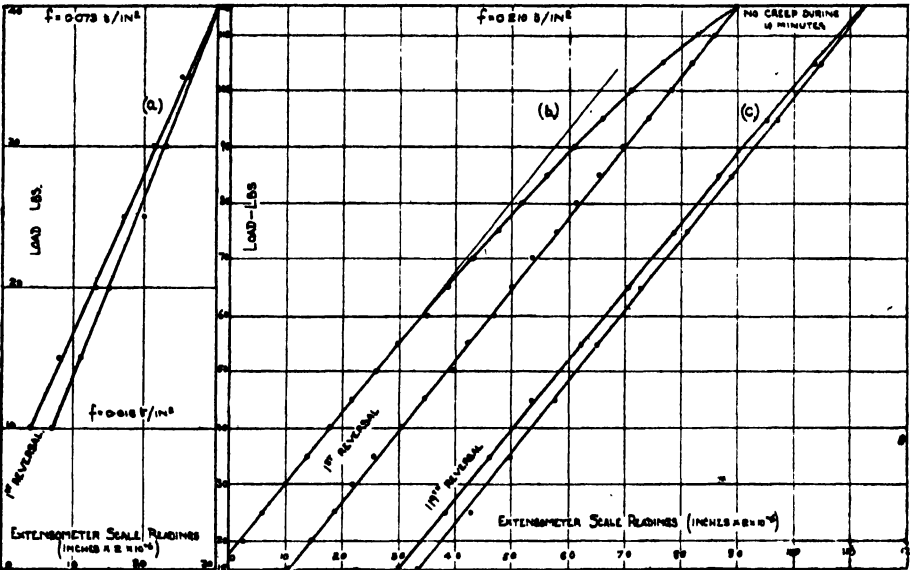


FIG. 20 (a). Effects of repeated tensile loading on a single crystal of aluminium; no appreciable range of primitive elasticity is exhibited.

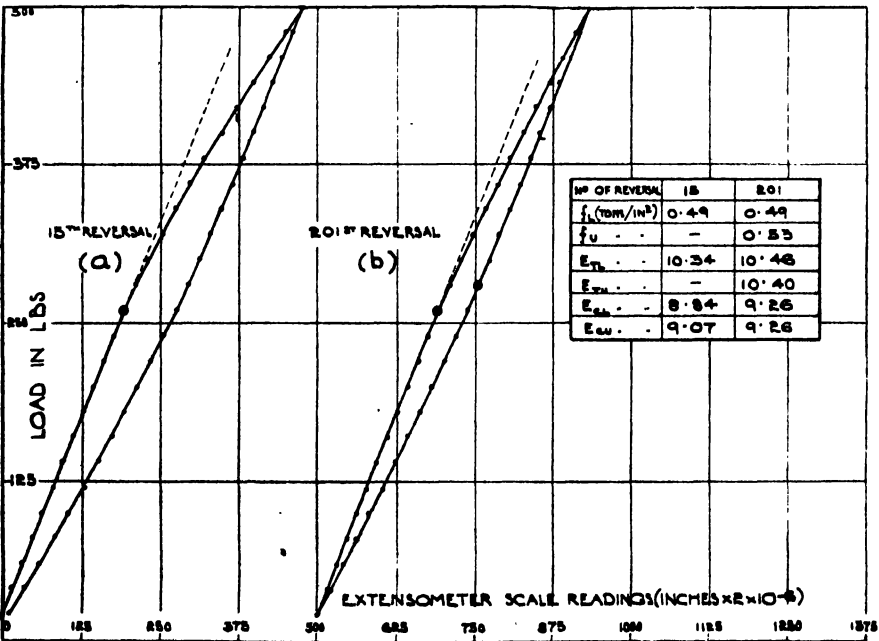


FIG. 20 (b). Effects of repeated tensile loading on a single crystal of aluminium; the approach to and the attainment of the cyclic state.

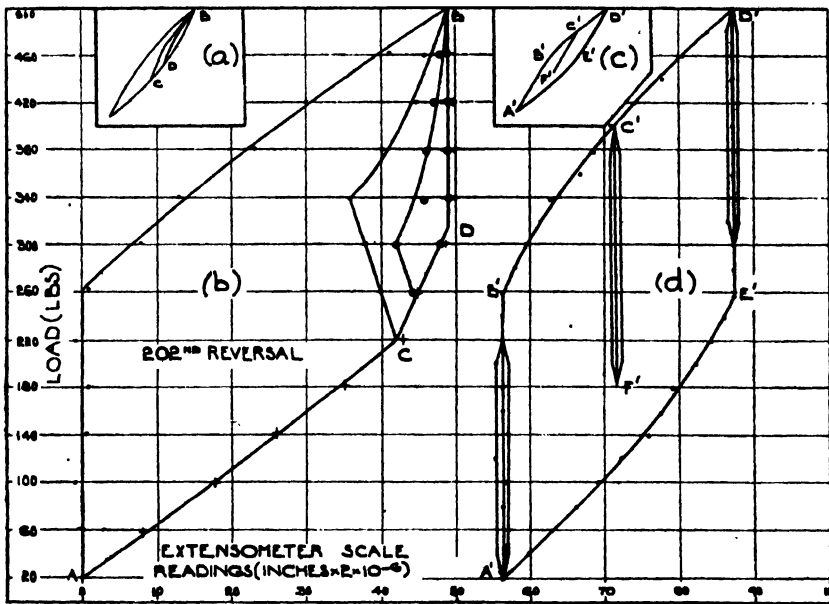


FIG. 20 (c). Effect of repeated tensile loading on a single crystal of aluminium; illustrating the state of elasticity obtaining within a "closed loop".

& Lovell²⁵ shews that the internal friction of materials like celluloid, glass and wood, as well as metals and alloys, obey the same law in that the frictional loss per cycle is practically independent of the frequency of the cycle. No survey of hysteresis can be complete without a reference to the work of Professor Mason, who has made an exhaustive study of the stress strain relations of specimens in the form of rotating bars subjected to a uniform bending moment. If the specimen is deforming elastically the displacement of the end of the specimen is parallel to the line of action of the applied loading, but if the specimen under test exhibits strain hysteresis, the displacement has a component in a direction at right angles to the line of loading. The direction of this component is determined entirely by the direction of rotation (clockwise or anti-clockwise) of the test piece. The work absorbed per cycle due to hysteresis can be determined by measuring the amount of the lateral component. The method of calculation is described by Mason in an interesting paper²⁶ entitled "The Mechanics of the Rotating Bar Test." In this way Mason has been able to estimate the discrepancy between the actual fibre stresses in a Wöhler test piece and the calculated value as usually determined assuming elastic²⁷ conditions. He found^{27, 28} with certain mild steels that the calculated limiting

25. "Internal Friction in Solids." Proc. Amer. Soc. Mech. Engrs., December, 1926.

26. Engineering, June 1st, 1923.

27. Rept. Brit. Assoc. Section G. 1923, p.386.

28. Rept. Brit. Assoc. Section G., 1924.

stresses were at least 8% in excess of the actual stresses present. The difference is even greater for solid round specimens under reversed torsional stresses amounting to between 10% and 13% for certain mild and medium carbon steels. It is precisely the effects of the different impressed conditions of test²⁹ that are responsible for the divergences between the limiting stresses of the same material obtained in direct stress and bending stress fatigue machines. It is apparent that the importance of the cyclical stress-strain relations obtaining in a fatigue test is not generally realised; in America recently the argument has been advanced—based on a few tests, of a decidedly inconclusive nature—that the lower value of the limiting range of stress usually obtained in direct stress tests is due entirely to eccentricity of loading.

SECTION VII.

FATIGUE PHENOMENA OF CRYSTALLINE AGGREGATES AS EXHIBITED BY CHANGES OF MICROSTRUCTURE.

The first epoch in the history of fatigue testing is associated with the names of Galton, Fairbairn and Wöhler; the second, equally significant, is marked by the work of Ewing, Rosenhain and Humfrey, who applied the metallurgical microscope to the study of the effects of strain upon the structure of metals, and thereby opened up an entirely new line of attack upon the problem of fatigue. Ewing and Rosenhain in 1889³⁰ and 1900³¹, shewed that metals remain crystalline when the form of the metal is altered by strain, plastic yielding being due to slip on cleavage or gliding planes within the crystals, and, partly (in some metals) to the production of twin crystals. In pure metals fracture occurred in an intra-crystalline manner, in some impure metals it occurred through the parting of crystals at their boundaries; in both cases, however, the plastic yielding which precedes fracture took place by slip. In 1902³² Humfrey performed his notable experiments on the effects of strain on lead; this is one of the earliest experiments made on large single metallic crystals. In the same year, Ewing and Humfrey³³ read their famous paper on the study of the changes in microstructure of iron under fatigue stresses. The apparatus used was a small Wöhler machine. The specimens (of Swedish iron) were of rectangular section (0.3in. x 0.1in.) one of the broad faces of which was polished and etched and examined at various intervals during a series of endurance tests. Their experiments are described in their own words as follows:—

29. See (a) "Impressed Conditions of Fatigue Tests," Griffith. Rept. Brit. Assoc. Section G. 1924.

(b) "Some Comparative Fatigue Tests in Special Relation to the Impressed Conditions for Test" Gough & Tapsell, No. 1012, Repts. & Mem. Series, Aero. Res. Ctee., April, 1926.

30. Phil. Trans. Royal Society, A., Vol. 193, 1899, pp.353/377.

31. Phil. Trans. Royal Society, A., Vol. 195, 1900, pp.279/301.

32. Phil. Trans. Royal Society, A., Vol. 200, 1903, pp.225/240.

33. Phil. Trans. Royal Society, A., Vol. 200, 1903, pp.241/250.

"In experiments made with stresses ranging from 14 down to 9 tons per sq. inch it was found that fracture resulted in *all* cases. The course of the breakdown was as follows:—The first examination, made after a few reversals of stress, shewed slip lines on some of the crystals, on many of them if the stress was comparatively great, but on a few only if the stresses did not much exceed 9 tons per sq. inch. At this early stage the slip lines were quite similar in appearance to those which are seen when a simple tensile stress, exceeding the elastic limit, is applied. Viewed under vertical illumination they appeared as fine dark lines. After more reversals of stress, additional slip lines appeared which had not been visible in the first instance, but the most conspicuous feature was that those which had been visible before became far more distinct and shewed a tendency to broaden. After many reversals, they changed into comparatively wide bands with rather hazily defined edges, losing entirely the fine and sharp character which slip lines present when they first appear. As the number of reversals increased, this process of broadening continued and some parts of the surface became almost covered with dark markings made up of groups of broadened lines. When this stage was reached it was found that some of the crystals had cracked. The cracks occurred along broadened slip-bands; in some instances they were first seen on a single crystal, but soon they joined up from crystal to crystal, until finally a long continuous crack was developed across the surface of the specimen. When this happened a few more reversals brought about fracture. . . . We have provisionally named a lower limit of 9 tons per sq. inch, but the experiments give grounds for believing that an even smaller stress will produce fracture in a similar manner, if the process of reversing the stress is continued sufficiently long." In one of their experiments, at an estimated maximum stress of 6.9 tons per sq. inch after three million reversals, only *one* slip band was observed on the crystal. Commenting on this, Ewing and Humfrey say: "Prior to this the same specimen had suffered one million reversals of a stress of 5.3 tons per sq. inch without showing the smallest sign of damage. It was only after increasing the stress to 6.9 tons per sq. inch that any action became apparent. It is an open question whether an isolated slip-band such as this would have led to fracture, if the process of reversal had been continued. At the conclusion of the experiment it was still confined to one crystal and it did not even extend all the way across that."

Ewing and Humfrey then suggested the following theory of fatigue:—"In repeated reversals of stress certain crystals are attacked and yield by slipping as in other cases of non-elastic strain. Then as the reversals proceed, the surfaces on which slipping has occurred continue to be surfaces of weakness. The parts of the crystal lying on the two sides of each such surface continue to slide back and forth over each other. The effect of this repeated sliding or grinding is seen at the polished surface of the specimen by the production of a burr, or rough and jagged irregular edge, broadening the slip-band; and

suggesting the accumulation of debris. Within the crystal, this repeated grinding tends to destroy the cohesion of the metal across the surface of slip and in certain cases this develops into a crack. Once the crack is formed it quickly grows in a well-known manner, by tearing at its edge, in consequence of the concentration of stress which results from lack of continuity. Engineers are familiar with the development of cracks, even in the most ductile materials, when these are initiated at air-bubbles or other flaws. The present experiments shew how a crack may be formed, without any flaw to serve as nucleus, the first breach of continuity being set up through repeated grinding on a plane of slip in perfectly sound metal." This theory, which became known as the "attrition" theory of Ewing & Humfrey, marked a great advance in the knowledge of fatigue and became very popular, being simple and employing the familiar conception of friction; it is, apparently, still accepted in certain quarters even to this day. It is founded on two assumptions:—

(1) The fatigue range is essentially a range of primitive elasticity; thus, the superior stress of the cycle cannot exceed the primitive elastic limits of the material.

(2) A slip plane on which slip has occurred is thereby rendered a surface of weakness to further load or reversal of the same load.

Four years later Stanton & Bairstow³⁴ published their observations on the changes in microstructure of iron and steel subjected to reversed direct stresses. They studied Swedish iron and a medium carbon (0.64%) steel. The phenomena of the gradual appearance, multiplication and development of slip bands into the site of cracks was precisely similar, in a general way, to those observed by Ewing & Humfrey. The development of a crack at the stress concentration formed at the root of a screw thread was found to be exactly similar; a point of interest was the unstrained condition of the crystals in the neighbourhood of the crack, indicating the great source of weakness at the change of section and shewing how extremely local fatigue failure may be. In the higher carbon steel considerable difficulty was experienced in detecting whether the slip-bands and subsequent cracks formed in the ferritic or pearlitic areas, but the course of the crack followed, generally, the ferritic areas surrounding the pearlite. It is important to note that observations were confined to changes occurring under *unsafe* ranges of stress.

The subject received no further detailed attention until 1920 when it became apparent at the National Physical Laboratory that the time had arrived for a further comprehensive research. Bairstow's³⁵ work had shewn that a material can attain an elastic state—consistent with a safe range of stress—after passing through a preliminary stage involving plastic deformation. Hankins³⁶ had shewn that the fatigue range of nickel, under reversed bending and direct

34. Proc. Inst. Civ. Engrs. Vol. CLXVI, 1905-1906, Pt. IV.

35. Phil. Trans. Roy. Soc. A., 210, 1910.

36. No. 789, Repts. & Mem. Series. Aero. Res. Ctee.

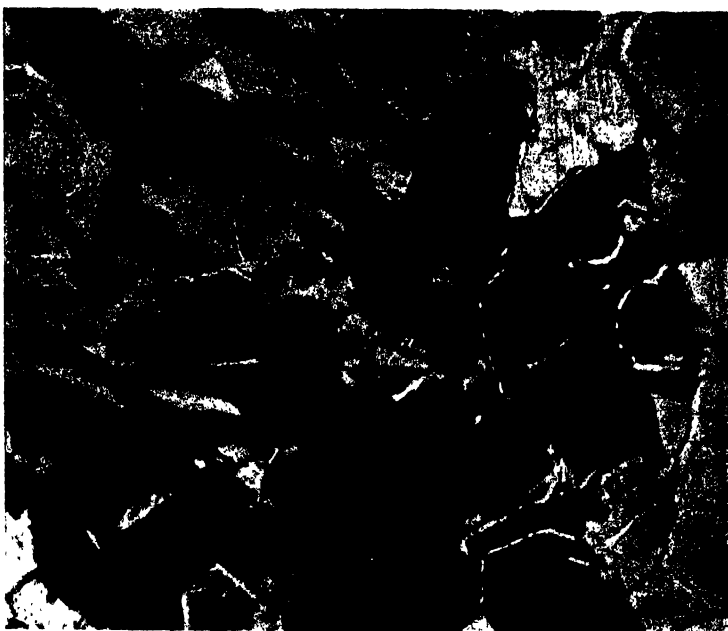


FIG. 21 (a). Microstructure ($\times 1400$) of mild steel after 30,000,000 repetitions of a safe range of bending stresses (± 15.4 tons/inch²).

stresses, considerably exceeds the range of its static yield points. The writer³⁷ had found that copper, a metal which exhibits large plastic deformations at practically all stresses, had a very definite fatigue range. Accordingly, a research³⁸ was commenced aimed at the study of changes of microstructure of metals—Armco Iron, various steels, copper, etc.—under safe and unsafe ranges of stress, including alternating and repeated direct stresses, reversed bending stresses (uniform bending moment) and reversed torsional stresses. In all cases, the fatigue ranges of the materials were determined by endurance tests on a very lengthy reversals basis (up to 250 millions reversals). It will be sufficient to discuss only four main aspects of this research.

(a) Slip bands were found to result from cycles of stress ranges whose magnitude was considerably less than the fatigue range. This applied to all the metals investigated under every type of stress system employed. In all our experience never has a metal been encountered which does not develop slip bands at a safe range of stress. Fig. 21 shews some typical examples.

(b) No marked difference could be detected between the slip bands due to safe or unsafe ranges.

(c) Broad dark bands similar to those of Ewing & Humfrey were observed,

37. Engineering, Sept. 8th 1922.

38. Gough & Hanson. Proc. Roy. Soc. A., Vol. 104, 1923.



FIG. 21 (b). Microstructure ($\times 1400$) of Annealed Armco Iron after 1,500,000 repetitions of a safe range of shear stress (± 6.0 tons/inch²).

but, under high magnification, these could be resolved into masses of fine slip bands; their appearance was totally incompatible with that of crevasses.

(d) The course of the crack (Fig. 22) included in its path some of the areas of heavy slip, and there is little doubt that the cracks were initiated in these areas. The crack obviously spreads owing to stress concentrations at its root. Fig. 23 shews the crack passing through a region free from previous slip.

It appeared to us that these experimental observations led to the inevitable conclusion that plastic deformation caused by fatigue stresses must be a strengthening or hardening influence (hardening is used in the sense that resistance to further plastic deformation by slip is *increased*). That such hardening is caused by severe statical stressing was, of course, well known; it now appeared certain that the same effect could be produced by fatigue stressing. Moreover, such hardening occurred when the applied range of stress was less

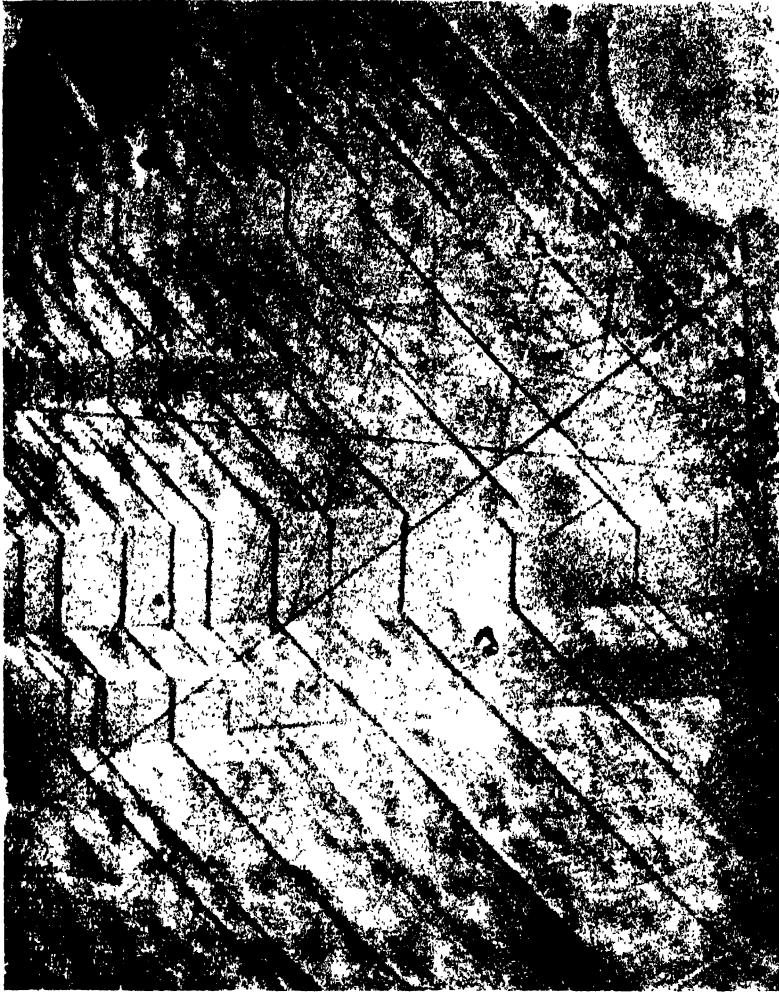


FIG. 21 (c). Microstructure ($\times 1400$) of copper after 3,000,000 repetitions of a single range of bending stresses (± 2.37 tons/inch²).

than, equal to, or greater than the safe range of stress. The initiation of the fatigue cracks was ascribed to the capacity of the material for cold working having been exceeded locally at various places throughout the mass. It is sufficient to say that the predicted hardening has since been proved both by means of ball hardness determinations—by Dr. Aitchison³⁹—and also by tensile tests⁴⁰ made on specimens previously subjected to safe or unsafe ranges

39. No. 923, Repts. & Mem. Series, Aero. Res. Ctee, May, 1924.

40. Bull. No. 142, Univ. Illin. Urbana.



FIG. 21 (d). Microstructure ($\times 1400$) of Annealed Armco Iron after 40,000,000 repetitions of a safe range of bending stresses (± 12.3 tons/inch²).

of stress. Owing to the lack of continuity of structure existing in the aggregate, it was not until large single crystals were available that our deduction that the actual slip plane is hardened by slip was also clearly established.



FIG. 22. Microstructure of Annealed Armco Iron showing areas of heavy slip and a typical fatigue crack.

It may not be apparent why Ewing & Humfrey's observations were so essentially different to those of later investigators. It has recently occurred to me that the cause of the discrepancy can probably be traced to the stress concentration occurring at the clamp of the test pieces used by Ewing & Humfrey, which reduced the safe range at this point to a value below that required to produce slip bands in the remainder of the test piece. Had their specimens been made with the usual transition curves, there is little doubt they would have observed marked slip band effects at safe ranges of stress. Some tests on this point are being carried out.



FIG. 23. View (under higher magnification= $\times 1400$) of the end of the fatigue crack shown in Fig. 22.

The changes in microstructure due to impact fatigue have been studied by Stanton & Bairstow⁴¹. They made the extremely interesting discovery that if the force of the impact was so small as to produce failure only after a great number of blows, slip bands of the usual type were produced, the course of the resulting crack usually choosing the ferrite constituent. On the other hand, when fracture occurred under a few blows only, the microstructure revealed large numbers of Neumann lamellæ, which are not removed by polishing.⁴²

SECTION VIII.

TYPICAL FATIGUE FRACTURES.

Much has been written about the "mysterious" appearance of the so-called "brittle" fracture of ductile materials under fatigue stresses. As a matter of fact, the nature of these fractures can be predicted and explained with fair certainty. The subject is best considered from two standpoints:—First, the total distortion, or change of external shape; secondly, the appearance of the face of the fracture.

41. Proc. Inst. Mech. Engrs., Nov 1908.

42. The following should also be consulted:—

(a) Pfeil. Carn. Schol. Mem. Jour. I. & S. Inst., Vol. XV., 1926.

(b) Rosenhain & McMinn, Proc. Roy. Soc. A., Vol. 108, 1925.

(1) TOTAL DISTORTION.

Bairdstow's work shewed clearly that the total distortion of the test piece under fatigue is *at least* equal to that occurring under the static application of the maximum stress of the cycle. Therefore, we may expect the total distortion occurring under fatigue to vary from a small value—sometimes imperceptible, at other times quite appreciable—when the mean stress of the cycle is zero, to an increasingly higher value as the mean stress of the cycle is increased. This is found to be the case; extensions of the order of 20%, or even 30%, can occur in metals like copper, brass, wrought iron, etc., even under *safe* ranges of stress. The *total distortion*, therefore, can vary from zero to a high value.

(2) APPEARANCE OF THE FRACTURE.

We have seen that the origin of fatigue cracks are usually extremely local. Favourable crystalline orientation for slip, stress concentrations due to form, surface defects, or the site of inclusions, etc., etc., are common places at which the first cracks appear. Once started, the crack is propagated without appre-

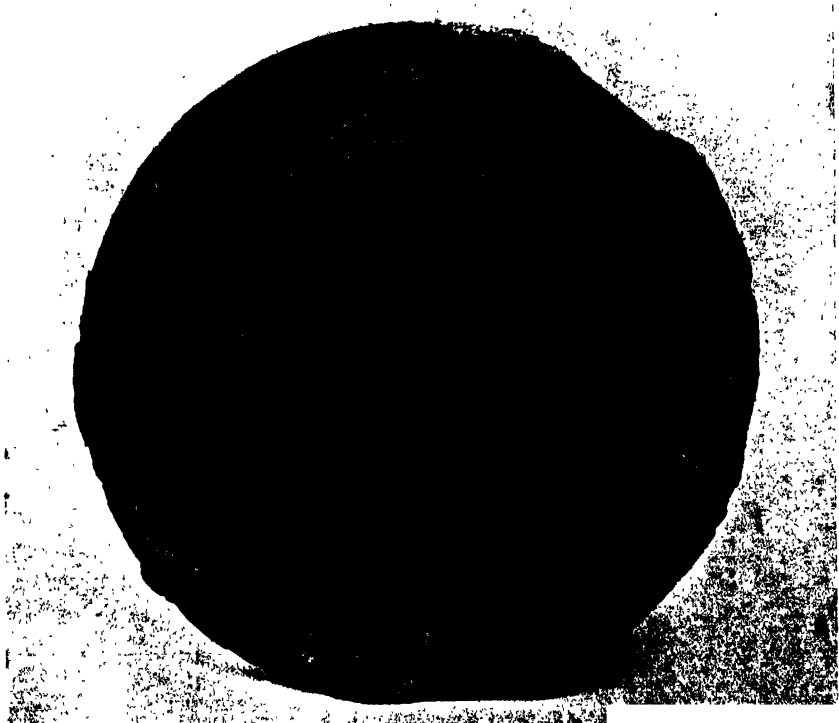


FIG. 24. Section of a crank-shaft fractured by fatigue stressing, and exhibiting the two typical "zones" associated with such failures.

ciable deformation of the crystals through which it passes, due to the high stress concentration at its root. The appearance of this part of the fracture is usually of a "smooth" type, and not "brittle" (the latter term is usually reserved for a "crystalline" appearance). At some stage of development the total cross section of the metal has been so reduced by the spreading fatigue crack that it is unable to resist the applied load, and a tearing fracture results. This second zone of fracture is similar in appearance to that produced by a static force or impact applied to a section containing a saw cut (in our case, the saw cut is the fatigue crack); hence, it may present a crystalline appearance together with the silky fibrous fracture associated with ordinary tensile failure of ductile metals. Fig. 24 is an excellent example of the two typical appearances exhibited on the face of a fatigue fracture. It is a photograph of a crankshaft which failed in practice. The fatigue cracks have started at the circumference and worked inwards in a uniform manner. The inner zone—of an entirely different appearance—marks the final sudden rupture. In the author's book⁴³ a number of very beautiful photographs—drawn from various sources—illustrate the several characteristic appearances of test specimens, also machine and engine components, which have failed by fatigue. An interesting photograph shews a failure commencing at a small fillet connecting the web and crankshaft of an internal combustion engine. The first stage of the spreading of the fracture, giving a rippled appearance, is clearly seen, also the final "static" rupture. A fractured propeller shaft is also illustrated; this is a case where failure commenced at a keyway due to excessive stresses set up by synchronous vibrations. Two other examples are particularly interesting as they shew *helicoidal* fractures due to torsional stresses. One is a fractured crankpin of a steam-driven pumping engine. Two spiral cracks are plainly visible. Another shews a spiral fracture in a crankshaft originating at an oil hole. Now torsion applied to a shaft produces maximum shear stresses on planes containing the axis, and many fatigue failures occur in these directions. On the other hand, the *helicoidal* fatigue fracture is very common in practice. In the 1920 Presidential Address to Section G of the British Association attention was directed to this phenomenon as one which had not so far received a satisfactory explanation, although of great interest and practical importance to designers. This matter has now been cleared up. Following a mathematical investigation by Southwell, we made a series of experiments which shewed that stress concentrations due to surface flaws was the explanation, and demonstrated experimentally that a material fracturing in the normal manner could be made, at will, to develop a *helicoidal* fracture. The original publication⁴⁴ contains a full statement of the theory and of a complete series of experiments.

43. "Fatigue of Metals," Gough (Chapter VIII.).

44. Southwell & Gough. "On the Concentration of Stress in the Neighbourhood of a small spherical flaw; and on the Propagation of Fatigue Fractures in 'Statically Isotropic' Materials": *Phil. Mag.*, Vol. 1, January, 1926.

SECTION IX.

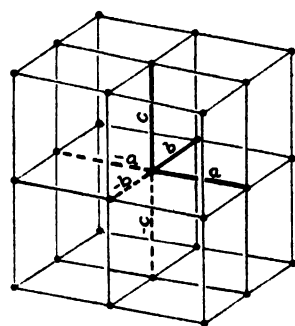
SPACE LATTICES, LATTICE DIRECTIONS, ALSO SOME USES OF THE STEREOGRAPHIC PROJECTION.

The third epoch in the history of fatigue testing was reached when it became possible to carry out tests on large metallic specimens, each consisting entirely of a single and continuous crystalline structure throughout, and, by means of X-ray analysis, to correlate the deformation of the crystal with the crystalline structure. In making possible this third and latest development, homage is due to Von Laué, who predicted that X-rays should be diffracted by crystals—acting as three-dimensional gratings—and to the Braggs, first for the enunciation of the fundamental law governing this diffraction, and also for a wonderful series of investigations into the actual structure of metals, alloys and other crystalline substances. The honours for devising methods of preparing large metallic single crystals rest with Czochralski and Gomperz, Carpenter and Elam, also, more recently, with Bridgman, and Edwards and Pfeil.

The opportunities thus afforded for the study of the effects of static and fatigue stressing upon the form of single metallic crystals correlated to their crystalline structure have been eagerly embraced by various investigators, and the results of their researches will be discussed in a following section. The object of the present section—for which some apology may be due—is somewhat different. It has been stated that some encounter difficulty in reading accounts of experiments made on single crystals due to some degree of unfamiliarity with the nomenclature and graphical methods of description which are adopted. To meet this difficulty, the present introductory section has been framed; it is necessarily brief and incomplete, but will, it is hoped, be of some use.

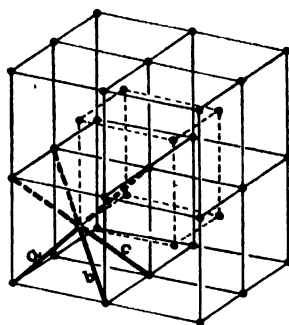
LATTICE STRUCTURE. (Fig. 25.)

A simple lattice (a Bravais lattice) is formed if three vectors, a , b , c , not lying in the same plane, and the three reversed vectors, $-a$, $-b$ and $-c$, are drawn from any origin O , and this procedure continuously repeated from the six end-points thus obtained, as shewn in Fig. 25(a). The directions of these three vectors are called the “primitive directions,” while the actual values of a , b and c are known as the “primitive translations.” The beautiful periodicity of structure obtained is characteristic of the crystalline state in which the points on the lattice correspond to the mean centres of action of the constituent atoms. There are, in some cases, several ways of forming any given lattice, by choosing different sets of vectors. In general, a parallel lattice, which is not simple, is produced if the same primitive directions and translations are applied not to the one origin O , but to a series of origins O_1 , O_2 , etc. It may also be regarded as a set of interpenetrating congruent simple lattices in which corresponding vectorial directions remain parallel. Bravais shewed that *fourteen* such parallel lattices exist. By suitable translations and rotations



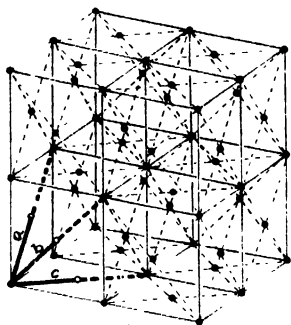
(A)

SIMPLE CUBIC SYSTEM.
 $a = b = c$



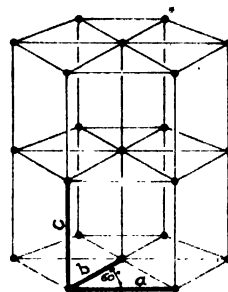
(B)

BODY-CENTRED CUBIC SYSTEM.
 $a = b = c$



(C)

FACE-CENTRED CUBIC SYSTEM
 $a = b = c$



(D)

SIMPLE HEXAGONAL SYSTEM
 $a = b$, lattice parameter $\neq c$
 $\frac{c}{a} = \frac{\sqrt{3}}{2}$, axial ratio.

FIG. 25. Diagrammatic Representation of some Lattice Systems.

a total of 230 *crystal groups* can be obtained from the original 14 parallel lattices. Every known crystalline form conforms to one of these crystal groups.

By taking three mutually perpendicular primitive directions and three equal primitive translations, the simple cubic lattice, shewn in Fig. 25(a), is obtained. The structure consists of a repeated arrangement of cubes, known as the elementary "cell" of the cubic lattice. The length of the edge of the cube is known as the "lattice parameter," and is usually denoted by the letter "*a*." No pure metals crystallise in this form. If an extra atom is placed at the centre of each unit cube of the simple cubic system, the *body-centred cubic lattice* is obtained (Fig. 25(b)). It may be treated as a complex lattice resulting from two inter-penetrating simple cubic lattices. But it is *really* a simple lattice of which the three primitive directions are three of the diagonals of the elementary cube, while the three primitive translations are equal to

each other and have a value of $\frac{\sqrt{3}}{2}$ times the side of the elementary cube.

Nine pure metals crystallise in a body-centred lattice. Excluding the soft alkali metals, Lithium, Sodium and Potassium, all of these, with the very important exception of iron, are characterised as brittle metals at air temperature. The *face-centred cubic system* may be considered as a simple cube with the addition of one atom at the centre of each of the six faces of the cube (Fig. 25(c)). This can be expressed as a complex lattice by the addition, to the simple cubic, of three superimposed parallel cubic systems, whose origins are situated at the centres of three adjacent cube faces. But it is easily expressed as a simple lattice whose origin is situated at the corner of an elementary cube, the primitive directions corresponding to the three intersecting diagonals of the cube *faces*, while the primitive translations are each equal to $\frac{\sqrt{2}}{2}$ times the cubic lattice parameter. Fifteen metals, all characterised by high ductility and malleability, conform to this lattice.

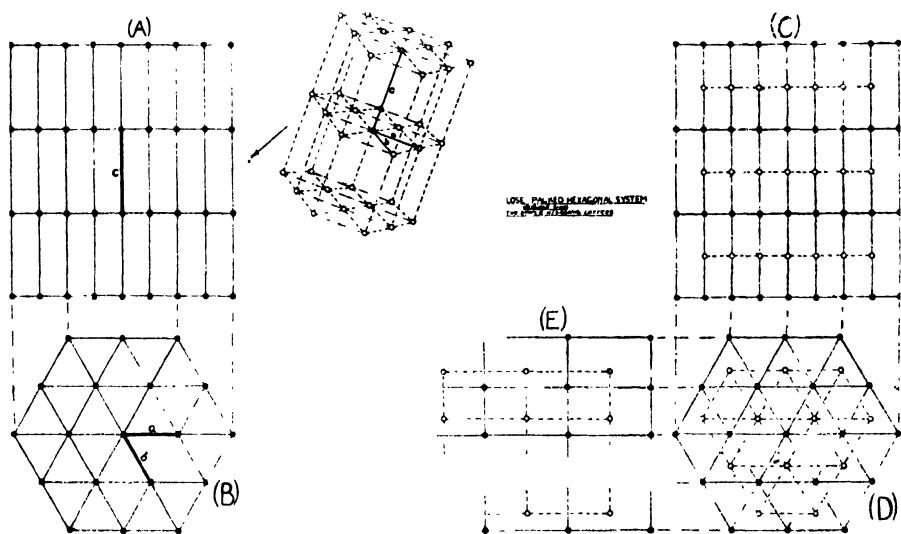


FIG. 26. Illustrating the derivation of the close-packed hexagonal lattice from two superimposed simple hexagonal lattices.

In connection with the present lecture, only one other form of lattice—the hexagonal—remains to be considered. This system has two primitive directions (equal primitive translations) intersecting at an angle of 60° , while a third and unequal axis is perpendicular to both. The length of the two equal primitive translations becomes the lattice parameter, while the ratio of the third primitive translation to the parameter is known as the “axial ratio.” (Fig. 25d). I know of no pure metals crystallising in this form. But

a number of pure metals conform to a structure—named Hexagonal close-packing—which is most easily produced by superimposing two simple hexagonal point lattices.

Fig. 26 (A and B) shews a simple hexagonal lattice in plan and elevation; note that in plan view, the lines joining the points form a series of equilateral triangles two sides of these triangles corresponding to two primitive directions. Now introduce a second simple hexagonal lattice of equal parameter and axial ratio in a particular position so that the second origin is $\frac{1}{2}c$ below the first and

also immediately below the centre of one of the equilateral triangles of the first lattice, the corresponding primitive directions of each lattice being parallel. We obtain the "hexagonal close-packing" shewn in Fig. 26 (C and D). Note that this is a true hexagonal close packing of spheres only if the axial ratio has the particular value of 1.63; this is overcome in other cases by considering the system as close-packing of ellipsoids of revolution. Zinc, which crystallises in this form—and to which further reference will be made—has an axial ratio of 1.860. This system *cannot* be reduced to a simple lattice with three primitive directions only, and it remains complex. Fig. 26 (C, D and E) shews that the individual planes of many sets of parallel planes of atoms are *not* equally spaced, and, in this sense, the lattice structure is irregular.

The above treatment of regular point groups with respect to certain primitive directions may be unfamiliar to some students and regarded as pedantic. But, as we shall see, the deformation of all metals hitherto studied has been found to be a process of simple shear involving a plane or planes of slip and a direction of slip. In every case, the important direction of slip has proved to be one of the primitive directions of the lattice, due to the fact—which can easily be demonstrated—that if a plane contains a primitive direction then that direction has a greater value of linear atomic density (number of atoms per unit length) than any other direction which is not a primitive direction of the lattice. Thus, if this method of building up the lattice structure is ignored, one of the most significant facts relating to the deformation of metals may be easily overlooked. For example, the cubic axes of the cubic system are unimportant in the deformation of metals crystallising in this form.

NOTATION OF PLANES AND DIRECTIONS.

On the table are three space lattice models representing, respectively, the face centred cubic, the body centred cubic, and the close-packed hexagonal lattices. It is apparent that the atoms are arranged on an infinite number of planes, and, further, that all the atoms can be considered as lying on a series of parallel planes of any one type. It is necessary first to relate any one of these planes to some conventional crystallographic axes. In the cubic systems, the three axes of reference commonly employed are the sides of the elementary cube. Fig. 27 (A) shews a plane, ABC, whose intercepts on the

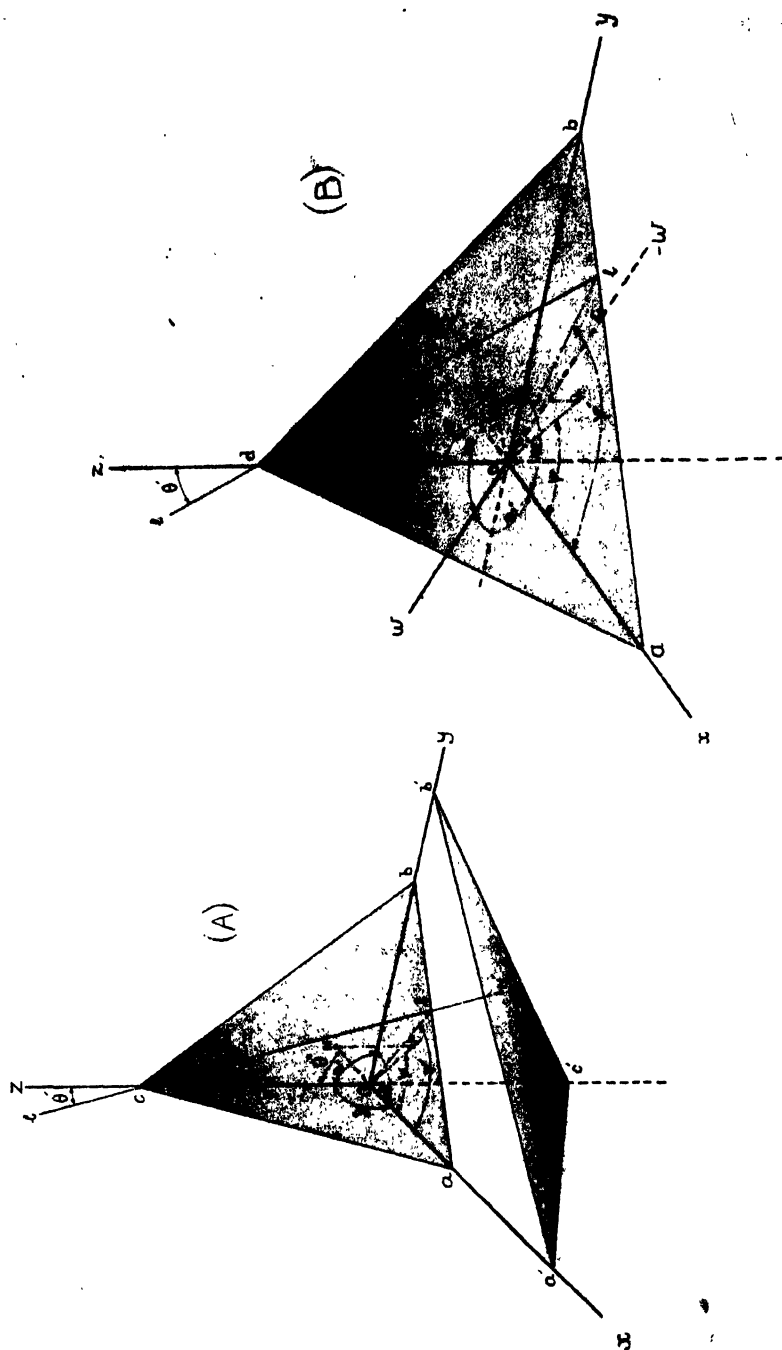


FIG. 27. Diagram of Co-ordinate Axes, and nomenclature employed to designate planes and lattice directions.

three axes OX, OY and OZ are OA, OB and OC, respectively. The plane is then completely defined by these intercepts. However, the *Millerian* system, of denoting the plane by the *reciprocals* of its intercepts is universally used in crystallography, the plane being thus known as the $\frac{1}{\overline{OA}}, \frac{1}{\overline{OB}}, \frac{1}{\overline{OC}}$ plane.

As we are not concerned with the actual *distance* of the plane from the origin, but only with its slope, the Millerian indices are usually expressed as whole numbers. The meanings of 111, 110, 112, $\overline{110}$ (the negative sign merely indicating a negative intercept) etc., planes, are now clear.

The normal to the plane is represented by the line ON. The true angle between ON and the axis OZ can be termed θ ; also, ON, the projection of the normal to the plane XOY, makes an angle of Ψ with the axis OX. Thus the plane can be more completely specified, for our purposes, by θ and Ψ , the spherical co-ordinates of its normal. Lastly, we often require to identify a line, such as LL, which lies in the plane. Now this line is the normal to a second plane, OA¹, OB¹ and OC¹. The line is then conveniently referred to as the $(\frac{1}{\overline{OA^1}}, \frac{1}{\overline{OB^1}}, \frac{1}{\overline{OC^1}})$ direction, or by its spherical co-ordinates, θ^1, Ψ^1 (Theta, Psi).

Turning to the hexagonal system, we could specify any plane by reference to the three primitive directions, or axes, *i.e.*, two axes mutually inclined at 60° (120°) and a 3rd perpendicular axis; with this convention any plane would be specified by *three* Millerian indices (as for the cubic system). But this would lead to a state of confusion, as similar planes of the same general form would be represented by Millerian indices of a totally different character. This difficulty is overcome by choosing *three* axes, mutually inclined at 120°, all lying in one plane, also a fourth axis perpendicular to the other three. Fig. 3 (b) shews the scheme, the Millerian indices of the plane ABDC being

$(\frac{1}{\overline{OA}}, \frac{1}{\overline{OC}}, \frac{1}{\overline{OB}}, \frac{1}{\overline{OD}})$ the fourth index referring to the vertical axis. It

follows that one Millerian index must be either negative or equal to zero; further, that the sum of the first three indices is *always* zero. Thus we obtain planes of the types 0001, 10 $\overline{10}$, 12 $\overline{10}$, etc. A direction is again denoted by the index of the plane of which it is the normal. The spherical co-ordinates θ, Ψ , also θ^1, Ψ^1 , are used, as with the cubic system, to denote a plane or a direction with respect to any two axes.

RESOLVED SHEAR STRESS.

It is essential that the exact meaning of resolved shear stress should be realised.

Fig. 28 shews a round bar subjected to a tensile stress, f . Consider a plane whose co-ordinates are θ, Ψ , with reference to the axis and a reference line RR. Resolving the stress in directions normal and parallel to this plane we obtain

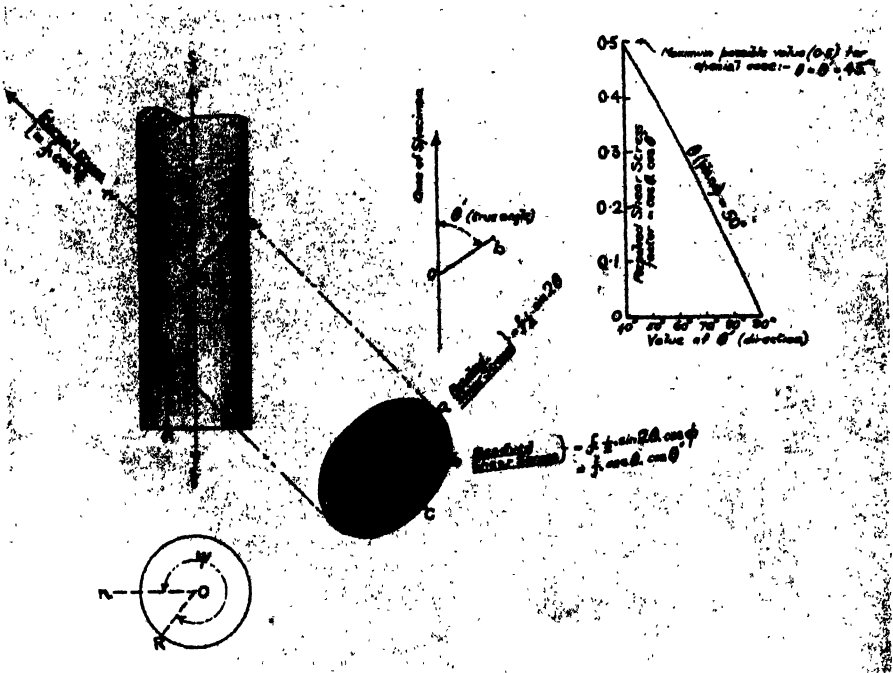


FIG. 28. Resolved Shear Stress.

$$\text{Normal Stress on plane} = f_n = f \cos^2 \theta \dots \dots \dots (1)$$

$$\text{Shear Stress on plane} = f_s = f \sin \theta \cos \theta \dots \dots \dots (2)$$

Now this shear stress is really the shear stress resolved in one direction only, namely OA, called the line of greater slope, whose θ^1 is $(90 - \theta)$. Consider another direction OB on the plane. Then if the angle AOB is represented by ϕ (Phi) the resolved shear stress in the direction OB is given by

$$f_{sr} = f_t \sin \theta \cos \theta \cos \phi \dots \dots \dots (3)$$

But as the line is contained by the plane, we have the simple relation

$$\cos \phi = \frac{\cos \theta^1}{\sin \theta} \dots \dots \dots (4)$$

where θ^1 is the inclination of the line OB to the axis. Hence the resolved shear stress on the plane, and in the direction OB, becomes equal to $f_t \cos \theta \cos \theta^1$. (θ^1 must lie between the limits $(90 - \theta)$ and 90°). The diagram inset in Fig. 4 shews how the value of the resolved shear stress factor ($\cos \theta \cos \theta^1$) varies for the case when $\theta = 50^\circ$.

STEREOGRAPHIC PROJECTION.

The geometry of crystals necessarily involves the use of the three dimensions of space; also, it rarely happens that the axis of a metallic single crystal coincides with one of the main crystallographic axes. Although this involves no

very great analytical difficulties, it is extremely convenient to portray crystal problems in two directions; for this purpose, the stereographic projection (whose origin is lost in antiquity) becomes invaluable. Fig. 29 (a) represents the elevation of a crystal specimen. ABCD is the intersection of a plane (whose normal is specified by the co-ordinates θ and Ψ , with respect to the specimen axis and reference mark 6 respectively), on a sphere centred at O. XOX^1 represents a diametral plane also passing through the point O. The

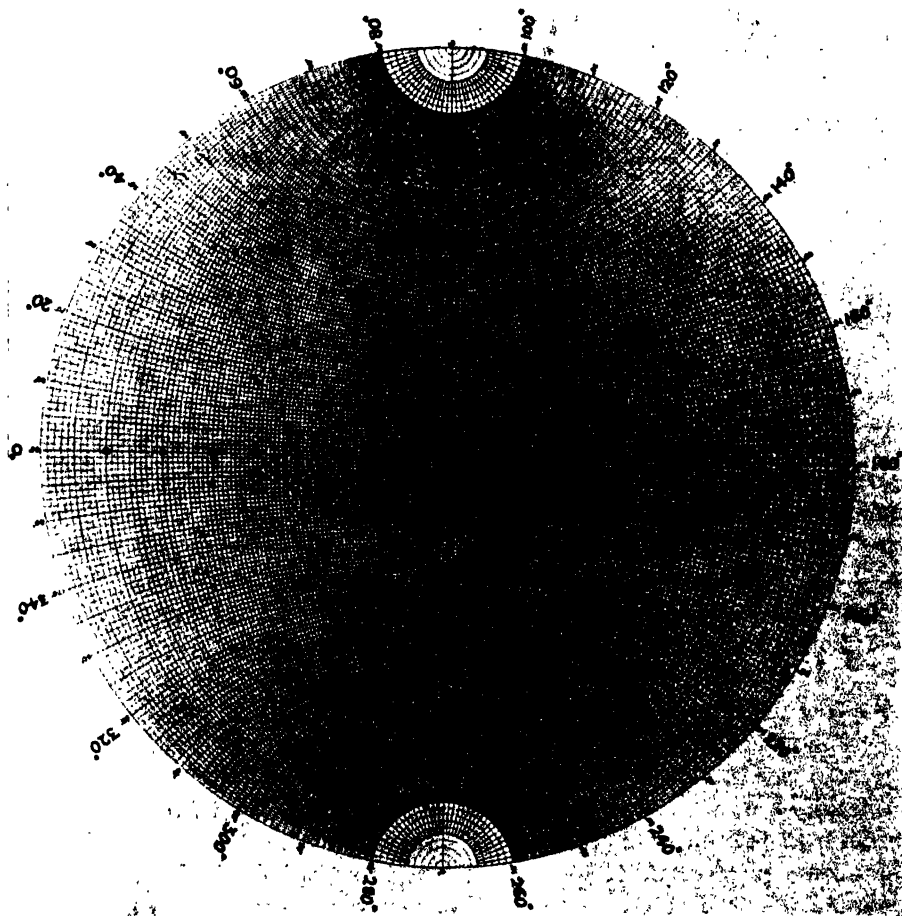


FIG. 30. Stereographic Net (12 inches in diameter) as used in crystallography.

point P is the lower end of that diameter of the sphere which is perpendicular to the diametral plane; it is termed the projection point. The points n^1 (elevation) and n (plan) represent the projection of the end of the normal on to the diametral plane. If now the trace of the plane on the sphere is projected in a similar manner we find that the curve produced (OBCDO) is an arc of a

circle. This is the fundamental property of the stereographic projection. If the upper hemisphere is inscribed by lines of latitude and longitude and these are projected in the manner described, we obtain a *stereographic net*, the projections of the latitude lines becoming arcs of circles (termed *zones*) having centres on the line joining the poles, while the longitude lines (termed *great circles*) have their centres on the equatorial line. We can now read off from the net that the co-ordinates of our plane are:— $\theta = 41^\circ$ and $\Psi = 131^\circ$.

Fig. 30 shews an accurate stereographic net, 12-inches in actual diameter; the great circles and zones are spaced 1° apart and readings can be estimated fairly accurately to 0.1° of arc.

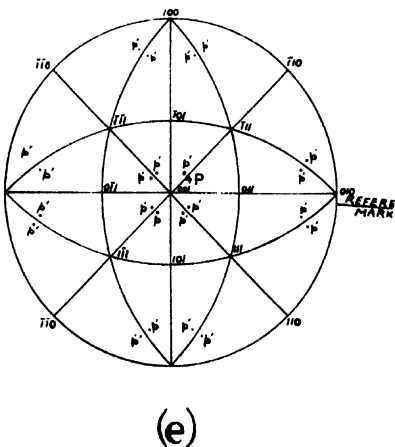
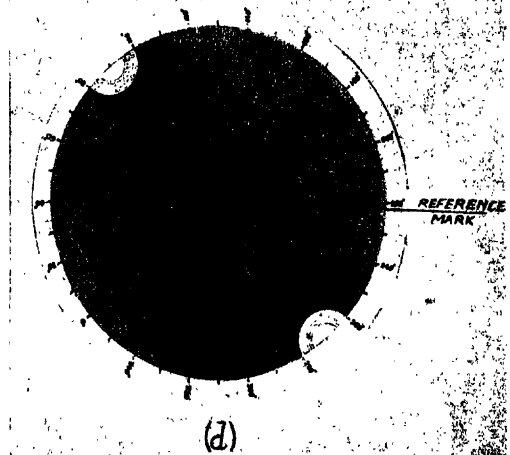
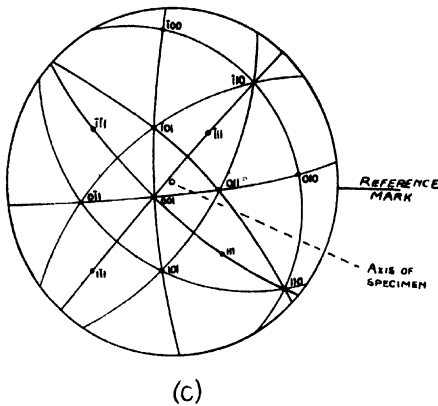
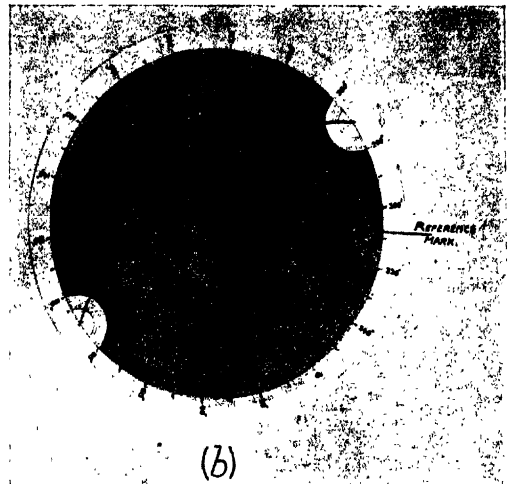
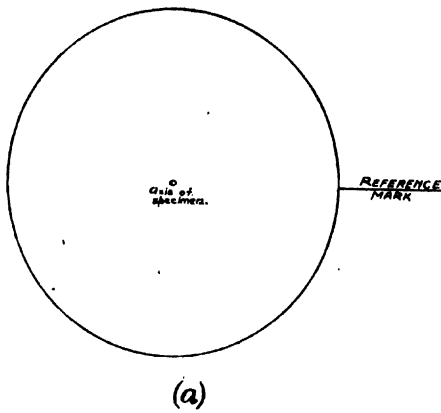
Some of the uses to which the net is put will be illustrated with regard to a typical cubic crystal. The results of an X-ray analysis (after correction) gave the spherical co-ordinates of the four octahedral planes as stated in Table 1.

TABLE 1.

SPHERICAL CO-ORDINATES AS DEDUCED FROM X-RAY ANALYSIS.

Octahedral Plane.		III	$\bar{1}\text{III}$	$\bar{1}\text{II}$	$\bar{1}\bar{1}\text{I}$
Spherical	Θ	$54^\circ 10'$	$59^\circ 6'$	$58^\circ 18'$	$70^\circ 26'$
Co-ordinates	Ψ	$308^\circ 0'$	$51^\circ 44'$	$149^\circ 42'$	$228^\circ 21'$

It is required to deduce the co-ordinates of the intersections of each of these planes with the remaining three; these intersections will give the normals of the dodecahedral (110 type) planes. On a piece of tracing paper choose a point to represent the axis of the specimen, describe a circle from this point equal to the diameter of the stereographic net, also draw a radial line to represent the reference mark on the specimen (Fig. 31*a*). Place the net under the diagram (Fig. 31*b*) in such a position that the reference mark coincides with the reading 308° (the required Ψ of the first plane), then measure off the required " θ " co-ordinate ($54^\circ 10'$) from the centre along the equatorial diameter towards the reading 0° . Mark this point on the diagram. It represents accurately the position of the normal to the III plane. Also draw in the great circle distant 90° from the normal; this is the projection of the trace of the III plane. Repeating this process for the other three planes, we obtain finally the polar diagram as shewn in Fig. 31*c*. Also, remembering that the cube faces bisect the angles between certain dodecahedral planes, by drawing in three more great circles, the positions of the cube faces can be indicated. The spherical co-ordinates of any of these planes can now be measured directly using the net. The diagram thus represents the orientation of the crystal with regard to the axis of the specimen. It is sometimes more convenient to shew the position of the specimen axis with regard to the structure on a diagram of which the pole coincides with a cube axis. This is easily done again using the net. Place



SPHERICAL CO-ORDINATES
DEDUCED FROM X-RAY ANALYSIS

OCTAHEDRAL PLANE		111	111	111	111
SPHER. CO-ORDS.	θ	$54^{\circ} 10'$	$39^{\circ} 6'$	$58^{\circ} 18'$	$70^{\circ} 26'$
	ψ	$308^{\circ} 0'$	$51^{\circ} 44'$	$149^{\circ} 42'$	$228^{\circ} 21'$

FIG. 31. Diagram illustrating some of the uses of the stereographic net in crystal problems.

the net under the diagram of Fig. 31c in such a way that the equatorial axis lies directly under the normal to 001 plane (Fig. 31d). Now rotate (graphically) the diagram about the polar axis of the net through an angle equal to the " θ " co-ordinate of the 001 plane. Then all points will move through this same angle measured along *zones* of the net. The diagram obtained is shewn in Fig. 31e, giving the required position. It will be noted that leaving the position of the planes unchanged I have drawn other great circles in such a manner that the diagram is now divided into 24 spherical triangles each precisely similar from a crystallographic point of view, the apices of each being the normals to a cube face (100), an octahedral plane (111), and a dodecahedral plane (110). Each triangle, in fact, is the smallest symmetry element of the cubic system. It is bounded by two planes of the 110 type and one of the 001 type, each of which are symmetry planes, *i.e.*, planes which divide the structure into two parts, each of which is a mirror image of the other. Therefore, we can depict graphically in one of these triangles every possible relative position of the specimen axis with the structure. This operation has been carried out with reference to the point P, and the 23 alternative positions—obtained by suitable rotations—are marked p'. Thus, to denote the relative position of the specimen and crystallographic axes, in crystal work any triangle can be used, but preference is usually given to one of the triangles of which the circumference of the circle forms one boundary, as such a triangle is of greater area than any of the inner triangles.

NOTES ON BOOKS.

THE LEGACY OF THE MIDDLE AGES. By various authors. Oxford: Clarendon Press. 10s.

In their preface the editors of this comprehensive and highly concentrated book point out the main difficulty that their collaborators had to face: the indefiniteness of the limits, geographical and chronological, of their subject. There was a second difficulty, almost as great. Were the various writers to say more about the "legacy" or about the "middle ages"? The Greeks, the Romans and the Hebrews "left us gifts marked by signs easy to recognise and appreciate." They initiated something which has been developed by the modern world. But the modern world has largely reacted from the mediæval world. The middle ages may even seem like a *détour* made by that portion of the human race which has, if nothing else, the greatest vitality and curiosity. Such a view is not superficial, yet it becomes so if the analogy is taken too literally; the fact is that we are the posterity of mediæval Europe, and the influences of Christendom are still everywhere felt.

The middle ages left two sorts of legacy; the artistic, which is, strictly speaking, a legacy, and the other-than-artistic, which is strictly speaking not a legacy. In the introduction Mr. Crump sets out first to sketch the framework of mediæval society, and then to give the reader an idea of the extent to which there were

exceptions to the general rules obtaining under feudalism. Professor Powicke follows with a broad-minded survey of the Christian life. This is a most important section. It is certainly amazing that the bellicose tribes and nations of Europe should have paid the allegiance they did to a God of mercy. To question the efficacy of the mediæval church, as Professor Reinach has said, is to make a miracle of her duration. One may also be allowed to wonder whether the imaginative cosmogonies of mediæval thinkers were not at least as good a basis for a complete inner life as the cautious and unspeculative empiricism fashionable among our own contemporaries. Mediæval man anyhow wished to see life as a whole. He accepted too convenient a solution of his fundamental problems, that offered by authority. But there is something to be said for not always following where the whims of innovation lead. A work like the *De Monarchiâ* of Dante suggests the mentality of a highly mature human being no less than do books on social and economic questions by the distinguished men and women of to-day.

The sections on mediæval art very naturally begin with architecture. The Gothic cathedrals are a solid legacy. They are beautiful, and they stand for the elements common to all Christendom in the middle ages. Impersonal, mysterious, the opposite of urbane, they retain the atmosphere of the supernatural in which their early congregations spent their leisured and reflective moments. The Gothic form, says Mr. Lethaby, "may be described and copied, but only the spirit made it a live thing." Neo-gothic is more rarely successful than neo-classical; this is perhaps because in all but time we are further from the twelfth century A.D. than from the fourth B.C.

Mediæval sculpture, and, we may add, wood carving, had a most wonderful vigour; they were, it is true, never without moral significance, but this only means that profane subjects were not in demand, and were therefore neglected. The declining centuries of ancient Rome were bad for sculpture, an art which seems hitherto to have been most successfully practised by comparatively unsophisticated craftsmen. Not till the twelfth century did it revive. The famous portal at Chartres "is the perfect expression of the art of the epoch." As often happens, what later artists gained in refinement they lost in the peculiar spontaneity which is an unmistakeable mark of inspiration.

M. Marcel Aubert, in his chapter on decorative and industrial arts, begins by pointing out that the latter "do not hold their due place in the history of art," largely because the very materials which the craftsmen used were "too tempting or too frail to survive the threatening hands of many generations." In the twelfth century the goldsmiths of Limoges were working "on an industrial scale for the whole of Christendom"; it should not be supposed that the mediæval market for such a commodity as theirs was a very restricted one. Whether in metal-work, tapestry or stained glass, the artists of the middle ages remembered that their purpose was to decorate, and to this end they adapted their technique, avoiding unnecessary details or showing an exquisite appreciation of detail as the case might be.

Two admirable chapters by Professors Jenkins and Foligno on mediæval literature, Latin and vernacular, are followed by one on handwriting. Here, indeed, we have a legacy: both the beautiful old books themselves and the characters which are the foundation of our modern type faces. The Carolingian scribes possessed a splendid calligraphy, and at the other end of the period, on the eve of the invention of printing, there were certain Italian scribes whose hand has never been surpassed. The humanistic minuscule was, indeed, based on the Carolingian, and this already had its roots in the remote past. Modern Roman types and characters derive

from the school of Tours, but so do modern Gothic types; for mediæval Gothic calligraphy was a direct development of the Carolingian minuscule, of which the humanistic script was a revival.

There is no space here to speak of Dr. C. R. S. Harris' article on mediæval philosophy, with which nobody is more competent to deal; his recent work on Duns Scotus has had the most friendly reception in the most varied quarters. Mediæval thinkers were anxious to reconcile the irreconcilable. They thought, or they hoped, that they knew the answer before they started the sum, but upon working out the figures they would naturally be brought to conclusions incompatible with their principles. Dr. Harris admits that there is little in modern thought which can be regarded as a direct legacy of the Middle Ages—"except perhaps the doubtful blessing of formal logic"—but asks us to remember that scholasticism both made Europe acquainted with the philosophical heritage of Greece and Rome, and founded the academic tradition of our universities.

Professor Adamson writes of mediæval education, of the Seven Liberal Arts, the *Trivium* and the *Quadrivium* on which were based the curricula of school and university. The late Sir Paul Vinogradoff is one of the authorities who deal with mediæval law, while Miss Eileen Power contributes a most interesting and entertaining account of the position of women in the feudal age. Professor Gras speaks of the economic activity of the towns, Mr. Johnson of the royal power and administration. Finally one of the editors, Mr. Jacob, writes learnedly of political thought.

GENERAL NOTE.

SERIES OF PUBLICATIONS ON NICKEL STEELS.—The Bureau of Information on Nickel, Ltd., have published the first of a series of publications on Nickel Steels. The present issue deals primarily with nickel and nickel-chromium steels. These are divided into two main classes, *viz.*, low nickel and high nickel. It is clear from this publication that nickel is being used at the present time for a great variety of alloy steels. Two of the largest fields of its application are the motor car and the aeroplane. Reference should also be made to the series of high magnetic permeability alloys which includes Permalloy, Permex, Rhometal and Mumetal. A new alloy of the Invar type, Elinvar, has recently been developed. This contains 36% of nickel and 12% of chromium. It possesses at the ordinary temperatures a practically invariable modulus of elasticity coupled with a very low thermal expansivity. The development of this alloy has extended the possibilities of the use of single-metal balances in high-grade watches and chronometers.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, OCTOBER 1..Chemical Industry, Society of, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 8 p.m. Mr. W. J. A. Butterfield, "Road Surfacing Materials."

TUESDAY, OCTOBER 2..Automobile Engineers, Institution of, at the Royal Automobile Club, Pall Mall, S.W. 8 p.m. Mr. Leslie H. Hounsfield, Presidential Address, "The Integrity of the Technical Man."

WEDNESDAY, OCTOBER 3..Analysts, Society of Public, at Burlington House, Piccadilly, W. 8 p.m. (1) Dr. G. W. Monier-Williams, "Polarimetric Determination of Sucrose in Milk and Sucrose Mixtures." (2) Mr. T. McLachlan, "The Analysis of Sugar Degradation Products by Selective Fermentation." (3) Dr. W. R.

Schoeller and Mr. E. F. Waterhouse, "Investigations into the Analytical Chemistry of Tantalum, Niobium, and their Mineral Associates. XIII. A New Method for the Separation of Zirconium and Hafnium from Tantalum and Niobium."

THURSDAY, OCTOBER 4..Aeronautical Society, at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 6.30 p.m. Mr. John D. North, "The Technical Development of the Aeroplane."

FRIDAY, OCTOBER 5..Chemical Industry, Society of (Chemical Engineering Group), at the ROYAL SOCIETY OF ARTS, Adelphi, W.C. 8 p.m. Mr. F. Heron Rogers, "Factory Floors."

SATURDAY, OCTOBER 6..L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Mr. James R. Ogden, "Recent Discoveries at Ur of the Chaldees."

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*All communications for the Society should be addressed to the Secretary, John Street,
Adelphi, W.C.(2.)*

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

FATIGUE PHENOMENA, WITH SPECIAL REFERENCE TO SINGLE CRYSTALS.

By HERBERT JOHN GOUGH, M.B.E., D.Sc., Ph.D.

(Engineering Department, National Physical Laboratory, Teddington).

V.

(Delivered February, 1928).

THE BEHAVIOUR OF SINGLE CRYSTALS OF METAL UNDER STATIC AND FATIGUE STRESSES.

SECTION X.

Arising from our observations¹ on the changes of microstructure of crystalline aggregates under statical and fatigues tresses, Dr. Hanson and I came to certain definite conclusions regarding the nature of slip and its consequences. We considered that failure under repeated stresses does not differ essentially from that due to static stresses ; that the effect of slip is essentially a hardening process resulting in increased resistance to further slip, and, whilst this hardening process was not confined to *safe* ranges of stresses, yet failure occurred by the formation of cracks. We surmised that the origin of these cracks was probably, in some manner, an indirect consequence of slip, but beyond confirming Ewing and Humfrey's observations that fatigue cracks usually have their origin in those areas of greatest previous plastic deformation, we were unable to determine

1. Gough & Hanson. Proc. Roy. Soc. A. Vol. 104, 1923. p.538.

what conditions were necessary to produce failure. It was recognised that the widely varying orientations of the crystals present in an aggregate, together with the presence of the inter-crystalline boundaries, were complicating factors involving unknown and indeterminate properties. Hence, it was apparent that the problem must be simplified by studying the fatigue properties of matter existing in a less complicated form, and through the kindness and co-operation of Professor Carpenter and Miss Elam we were enabled to take up the study of the fatigue of large single crystals of aluminium. Recently, the work has been extended to single crystals of iron, kindly presented by Professor Edwards and Mr. Pfeil, and at the present time, a commencement is being made on the fatigue properties of single crystals of zinc and antimony which have been prepared in the Metallurgy Department of the National Physical Laboratory. Before describing some of this work, I wish to make a brief summary of the work of other investigators on the *static* deformation of single metallic crystals. Such a summary, in connection with the present subject is not only desirable as drawing the attention of engineering students of fatigue phenomena to these researches—the importance of which *cannot be* over-emphasized—but is absolutely necessary, as otherwise a tendency may be developed to regard fatigue phenomena and failure as being unrelated to deformation and fracture under static loading, whereas each new investigation brings out more clearly that both types of failure are intimately related, and that when these failures are studied in their greatest detail—namely, in relation to the atomic structure—the underlying causes of the breakdown of cohesion in both cases are of a precisely similar nature.

The first accurate study of the deformation of single metallic crystals is described in a paper by Mark, Polanyi & Schmid in a paper* published in December, 1922. Using wires of approximately circular section (0.5 m.m. to 2.0 m.m. diameter) and subjecting them to a static tensile stress, these authors found that the section deformed into an ellipse, the ratio of the principle axes of which was nearly equal to the ratio of the final to the initial length of the stretched wire. They shewed that this type of deformation was consistent with the view that the material deformed by slip on one set of parallel planes; and by considering measurements of the section and of the strain markings on the stretched wire in conjunction with the orientations of crystallographic planes (as determined by X-ray analysis) they reached the conclusion that, in general, this slip occurred on the basal plane in the primitive direction most nearly coincident with the direction of maximum resolved shear on the basal plane. During deformation the angle between the axis of the specimen and the slip direction, and hence also the angle between the axis of the specimen and the basal plane, thus tend to be reduced. The authors shewed that the magnitude of these angles when fracture occurred depended upon the temperature—decreasing as the temperature increased. Thus, at 205°C. the limiting

angle between the axis and the basal plane was about 2° , while at -190°C . no measurable deformation was obtained with any basal plane orientation. Moreover, at any given temperature, the elongation prior to fracture of a wire depended upon the initial inclination of the basal plane to the axis in that wire, so that if this inclination was less than the limiting angle corresponding to the given temperature the wire was "brittle" and fractured with practically no elongation, while with favourable initial orientation and at high temperatures extensions up to 1700% could be obtained. In the later stages of deformation of the more ductile wires and particularly at high temperatures the authors surmised that slip occasionally occurred on first order prismatic planes; but they were unable to identify the slip planes or determine the direction of slip on these planes. This work of Mark, Polanyi & Schmid, bringing out clearly the mode of deformation of a single crystal on a crystal plane in a definite crystallographic direction, with the attendant consequences of change of shape and "rotation" of the lattice structure, represented one of the most significant advances ever made in the study of the deformation of metals; a brief incomplete summary, in English, has been made in a recent paper by Polanyi³, but the original publication should be consulted.⁴

Three months after the publication of the paper by Mark, Polanyi & Schmid, on the distortion of zinc crystals, Taylor & Elam⁵ described the results of their famous experiment on the distortion of an aluminium crystal under static tensile straining. A square specimen, 1 cm. side and 20 cm. in length was permanently strained until it fractured. At various stages during the test, measurements were made of the positions and inclinations of a number of reference marks placed on the sides of the specimen prior to the test; the specimen was also X-rayed at these stages. The method adopted in determining the type of deformation was perfectly general and consisted in determining the position of lines of particles which remained undistorted during any particular stage of the extension. In essence, it may be expressed as follows (Fig. 32): At any point in a strained material, the strain in the direction l, m, n , (referred to the axes of principal strain) is

$$\sqrt{l^2 (1 + e_x)^2 + m^2 (1 + e_y)^2 + n^2 (1 + e_z)^2} - 1$$

where e_x, e_y and e_z are the principal strains. If this expression reduces to zero—as for an unstrained line of particles—we have

$$l^2 (1 + e_x)^2 + m^2 (1 + e_y)^2 + n^2 (1 + e_z)^2 = 1$$

so that the *envelope* of all unextended directions is, in general, a *cone*. By making suitable strain measurements, it is possible to determine the *axes* and the amounts of the principal strains and thus to deduce the equation to

3. Trans. Fara. Soc., Vol. 24, Pt. 2, Feb. 1928, p. 72.

4. NOTE.—For some further work on zinc, the following may be consulted:—(a) Mathewson & Philips. (b) Wilson & Hoyt. (c) Hoyt. Proc. Amer. Inst. Min. Met. Engrs. (1927), also a paper, by the present writer and a colleague, which will be published shortly.

5. Bakerian Lecture. Proc. Roy. Soc. A., Vol. 102, 1923.

In a strained material, the strain of a line of which the direction cosines, referred to the axis of principal strain were l, m, n in the unstrained state, is

$$\sqrt{l^2(1-e_x)^2 + m^2(1-e_y)^2 + n^2(1-e_z)^2} - 1 \quad \text{where } e_x, e_y, e_z \text{ are the principal strains.}$$

If this is equated to zero, we have an equation to the cone of unextended directions

$$l^2(e_x^2 - 2e_x) + m^2(e_y^2 - 2e_y) + n^2(e_z^2 - 2e_z) = 0$$

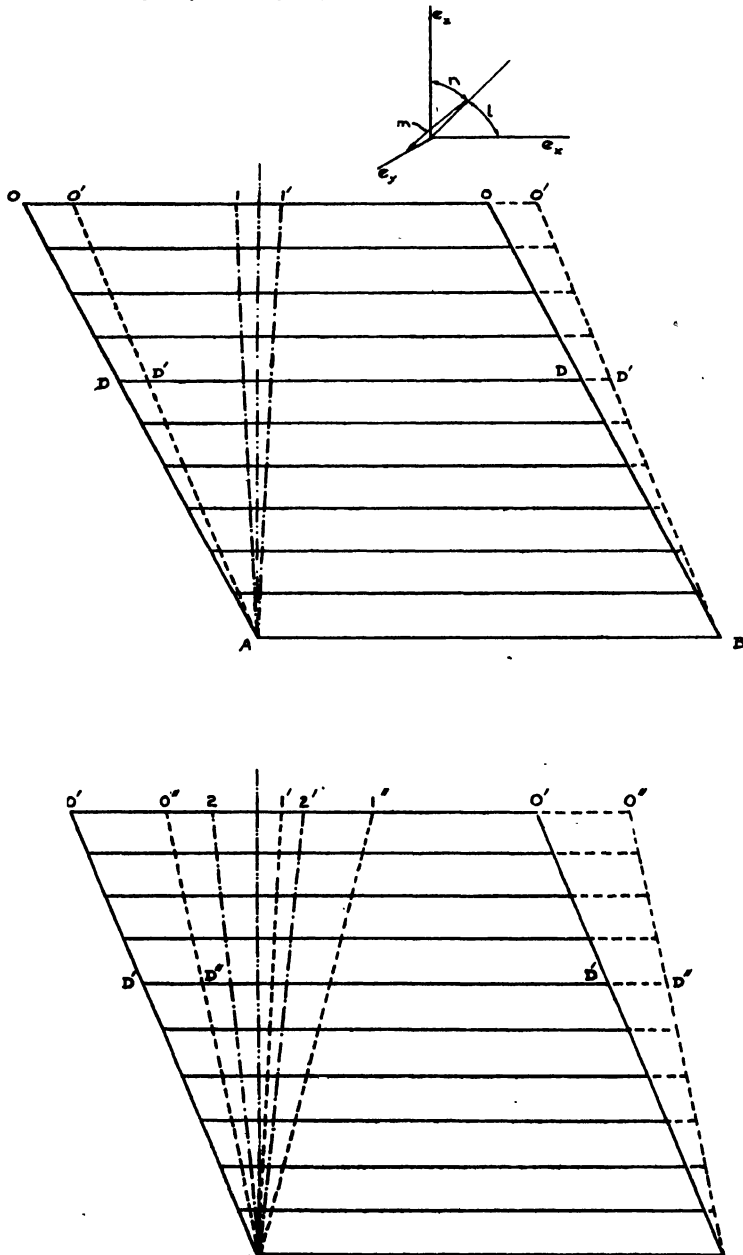


Fig. 32. Diagrammatic Representation of Taylor's Strain Method.

the unextended cone. Taylor & Elam did not explicitly determine the principal strains, but proceeded direct from the primary distortion measurements to the equation of the zone. Now, if the material deforms by a simple shear, the unexpected cone degenerates into two planes, the direction of slip being contained by one plane and making an angle of 90° to the intersection of the planes. Taylor and Elam found that the unextended cone, in their specimen, *did* degenerate into two planes, one of which bore a strict relation to the position of the crystallographic axis, while the other bore no relation to the crystal form, its direction depending largely on the *amount* of strain. Fig. 32 will make this quite clear. A pile of cards, OABO, is deformed by two successive shears into the positions O'ABO' and O''ABO''. After the first deformation the unextended cone consists of the two planes, 1A and DD (the new positions are 1'A and D'D'); after the second, it consists of the two planes, 2A and D'D' (the final positions are 2'A and D'D''). Thus, the unextended cone consists, at any stage, of one plane which varies with the *extent* of the deformation, and a second plane, which remains constant throughout; the latter is the slip plane. Hence, by referring the unextended cones to the crystal structure of the specimen, Taylor and Elam deduced that the slip plane was always an octahedral plane, and that the direction of slip was the most highly stressed primitive direction (110) contained by the slip plane. In the particular specimen used, it was found that deformation proceeded by shear on the same set of octahedral planes, and in the same slip direction, for extensions up to 40%. For extensions from 50% up to fracture, distortion was no longer one of simple shear on one set of planes, but proceeded by simultaneous or alternate slip on two sets of octahedral planes, each equally inclined to the axis of the specimen. In a later paper* further experiments were described which established the general mechanism of the deformation of aluminium under static tensile forces:—The slip plane is always an octahedral plane (which is the plane of greatest atomic density in the face centred lattice); the slip direction is always one of the three directions (crystallographically similar) of greatest linear atomic density (primitive directions) contained by the octahedral planes. As there are four sets of octahedral planes, each containing three primitive directions, twelve possible directions of slip exist. The actual slip plane and slip direction is determined by the simple condition that the value of the resolved shear stress on the plane in the slip direction is greater than that in any other similar direction. Slip thus proceeds by simple shear on one set of octahedral planes and changes at a later stage into a process of double slipping on two equally inclined octahedral planes; during most of the deformation, the axis of the specimen is rotating relative to the crystallographic axes. A stage in the deformation is reached at which the axis is equally inclined ($61^\circ 52'$) to the slip planes and makes an angle of $54^\circ 44'$ with their intersection. During any subsequent deformation no further relative rotation occurs.

A study of Figures 33⁷ and 34⁷ will show how the process of simple shear on parallel planes in a given direction produces the following main results:—(a) The inclination of the slip-plane to the axis of pull decreases, (b) the slip direction approaches into coincidence with the axis of pull, (c) the cross-section of the specimen—originally circular—becomes elliptical, the major axis of the ellipse (in the general case) becoming greater than the diameter of the original circular cross-section.

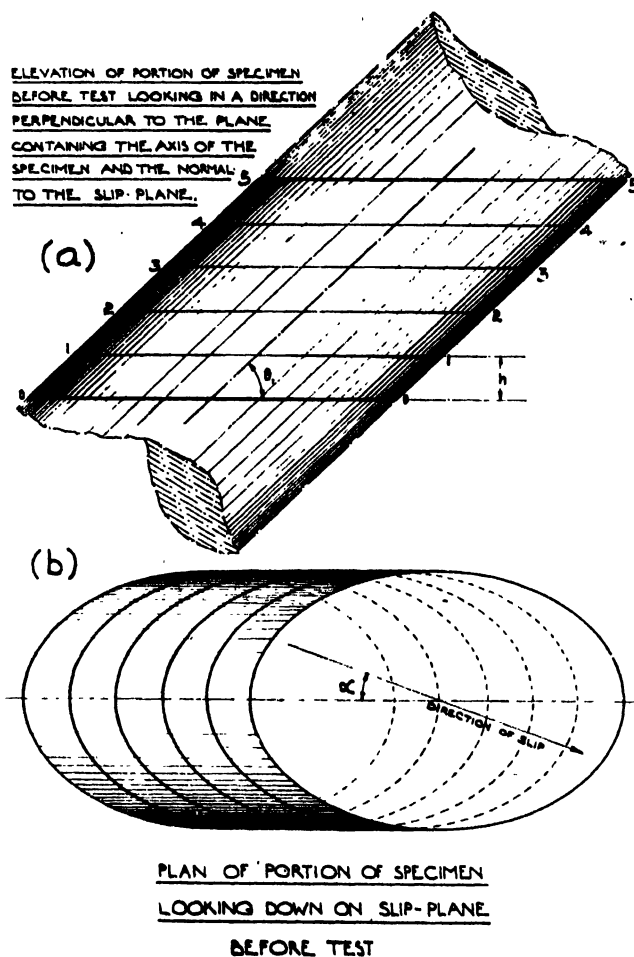


FIG. 33. Diagram illustrating the change in cross-section, also the relative movement between the specimen and crystallographic axes, due to deformation by a process of simple shear in a certain slip direction. Before slip.

7. NOTE.—For the originals and complete description of these diagrams, see "The Behaviour of Single Crystals of Aluminium under Static and Repeated Stresses." Gough, Hanson and Wright, No. 995, Reports & Memoranda Series, Aero. Res. Ctes., Nov. 1924 (H.M. Stationery Office, price 3/6d.).

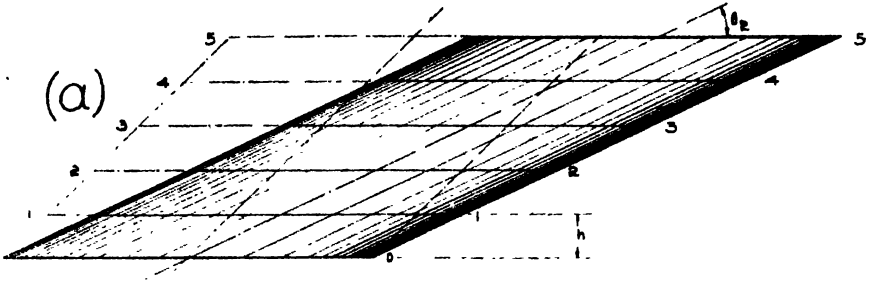
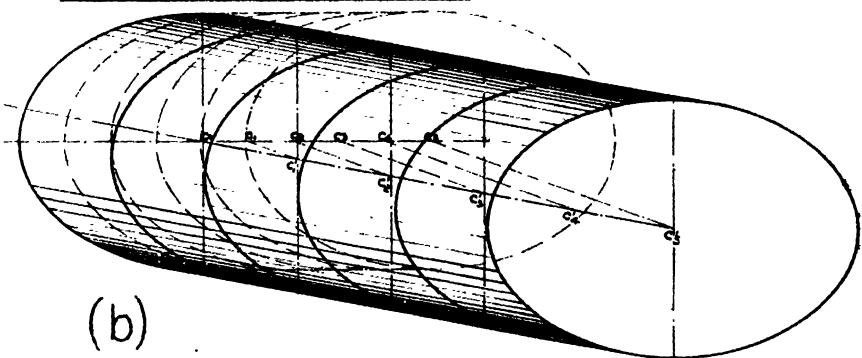
ELEVATIONAFTER SLIP HAS TAKEN PLACEPLANAFTER SLIP HAS TAKEN PLACE

FIG. 34. As Fig. 33, but after slip has taken place.

In the tensile tests on Zn. and Al., described above, it is apparent that the determining factor of the deformation is the value of resolved shear stress on the plane of slip in the slip direction ; no evidence is obtained of the effect of the normal stress on the slip plane in assisting or retarding the deformation. This aspect was studied by Taylor and Farren⁸ using aluminium specimens subjected to *compressive* loading. The deformation obeyed exactly the same laws (resolved shear stress) as determined in the tensile tests, and a comparison of the stress-strain diagrams obtained under the two types of loading shewed that the effect of the normal stress was inappreciable. Schmid⁹ has also shewn that with bismuth and some other metals, the normal stress does not affect the resistance to shear. Gold, silver and copper, like aluminium, crystallise

8. Proc. Roy. Soc. A., Vol. 111, 1926 ; see also Proc. Roy. Soc. A. Vol. 116, 1927.

9. Zeit. fur. Physik., Vol. 39, p. 359, 1926.

according to the face-centred cubic lattice and Elam¹⁰ has shown that the mechanism of deformation is substantially the same as in aluminium. For a study of the deformation of single crystals of metallic alloys reference should be made to three papers by Elam^{11, 12, 13}. The metals investigated were:— (a) Al-Zn. Alloys (solid solutions containing from 5% Zn. to 18.6% Zn), (b) α -Brass (70% Cu. 30% Zn.), (c) Copper-Aluminium Alloy (5% Al.). In each case, deformation proceeded by slip on a crystal plane or planes in a crystallographic direction according to the maximum resolved shear stress law.

Goucher¹⁴ has made a study of the deformed single crystals—in particular the fractured crystals—which are produced by the extension and fracture of fine tungsten wires composed of crystals, many of which occupy locally the complete volume of the wire. As tungsten (which crystallises in the body-centred lattice) is sometimes brittle at air temperature, the test wires were strained at the high temperature of 3000°K.¹⁵ The mechanism of the deformation was deduced from the angles of the wedges formed at the point of fracture, as correlated with X-ray analysis of the structure. Goucher deduced that deformation proceeded by slip on 112 planes in the 111 direction. The 111 direction is a primitive direction of the lattice and hence is a line of greatest linear atomic density; 112 planes, however, are less densely populated than either the 110 or 100 planes.¹⁶

Thus, Goucher's work was the first indication that in the deformation of single crystals the condition that the direction of slip shall be a primitive direction of the lattice may be of equal or greater importance than that the slip plane must be a plane of the highest possible atomic density. Probably the most important feature of Goucher's work was the investigation, using accurate X-ray methods, of the effects of plastic strain upon the atomic structure; further reference will be made to this aspect.

The problem of producing large single crystals of iron—the most interesting metal to engineers and metallurgists—was solved finally by Edwards & Pfeil.¹⁷ From some compression tests, Pfeil¹⁸ concluded that iron deformed by shear on 112 planes in the 111 direction (primitive direction). But the characteristic form of slip bands (varying from straight lines to a wavy, branched formation) which have been familiar for many years, are difficult to reconcile with slip on *any* one set of parallel planes.

10. Proc. Roy. Soc. A., Vol. 112, 1926.

11. Proc. Roy. Soc. A., Vol. 109, 1925, p. 143.

12. Proc. Roy. Soc. A., Vol. 115, 1927.

13. Proc. Roy. Soc. A., Vol. 116, 1927.

14. Phil. Mag., Vol. 48, p. 229. Aug. 1924; also Phil. Mag. Vol. 48, p. 800. November, 1924.

15. NOTE.—Melting point of tungsten is 3570°K.

16. The relative densities of the 110, 100 and 112 planes are respectively, 1.414, 1.0 and 0.814.

17. Jour. Iron Steel Inst. 1923, No. II, p. 263; 1924, No. 1, p. 129; also 1925, No. 2, p. 79.

18. Carn. Schol. Mem. I. & S. Inst., Vol. XV, 1926.

In 1926, Taylor and Elam¹⁹ published the results of tension and compression tests made on iron crystals supplied by Edwards & Pfeil. The "analysis of strain" method—originally used for aluminium crystals—was again employed, and the unstretched cone determined. The same degenerate form of cone—consisting of two planes—was obtained and the direction of slip was identified, in every case, as the 111 direction; the process of deformation was also found to be one of simple shear on parallel planes. When the slip plane, however, was compared with the crystallographic structure, although in one specimen it proved to be a 112 plane, yet, in the general case, it did not coincide with any crystallographic plane of low indices, but was determined by the condition of actual maximum resolved shear stress in the slip direction. Now, such a process of shear could appear as the resultant effect of slip on *two* sets of planes, each containing the slip direction, the ratio of the relative amounts of slip being so adjusted that the total distortion produced was equivalent to slip on any given plane through their line of intersection. The distortion method would fail to reveal this action if it were in operation. Accordingly, an examination was made of the slip bands formed on the polished surfaces of the specimens. Taylor & Elam decided that the evidence was strongly against the hypothesis that distortion is caused by slip on two crystal planes, but suggested that the nature of the slip bands produced could be explained on a new hypothesis, that under a shearing stress the crystal divided itself into rods, whose axes were parallel to the slip direction, and which can move relatively to each other in this direction only. This suggestion was demonstrated by an ingenious model which illustrates that a type of deformation could be produced which, while in accordance with the results of the distortion tests made on the actual crystals used in the research, also produced slip bands whose shape varied from a series of straight parallel lines—produced at that point on the surface of the specimen at which the slip direction was tangential to the surface—to a maximum degree of waviness at a point distant 90° as measured round the specimen.

The above summary—necessarily brief—indicates the main features of the deformation of single metallic crystals when deformed by statical forces. We will now consider their behaviour under fatigue stressing.

THE BEHAVIOUR OF SINGLE CRYSTALS OF ALUMINIUM UNDER FATIGUE STRESSES.

The majority of the fatigue work on single crystals has been carried out using aluminium, and this work will be discussed in the present paper.²¹ The

¹⁹ Proc. Roy. Soc. Vol. 112, 1926, p. 337.

²¹ NOTE.—A research into the mechanism of deformation of a single crystal of iron, under fatigue stresses, has recently been completed by the writer, and a paper on this work has been submitted to, and accepted by, the Royal Society. As this paper has not yet been read, reference to the contents cannot properly be made here. (Later:—The paper referred to has since been published; See Proc. Roy. Soc., Vol. 118, 1928, p. 1).

various researches have been fully reported in a number of published papers;¹⁰⁻²⁰ hence, I propose to discuss the results obtained in view of the light they throw upon the general problems of fatigue, at the elucidation of which this work has been directed. Some of these problems may be concisely summarised in the form of leading questions. Before stating these questions the general methods adopted in the researches may be briefly stated:—A specimen is machined from a crystal. Following a prolonged etching treatment to remove the effects of the machining operations the specimen is submitted to X-ray analysis. The surface is then given a high metallurgical polish and the shape of the cross section is accurately determined by high power projection methods. At various stages during the actual test, the surface is examined for slip band markings, the nature and inclination of which are accurately measured and recorded photographically. Additional X-ray analyses are made at various stages; any changes in the shape of the cross section of the specimen are also determined. Using the various measurements and the X-ray readings, the deformation is correlated to the crystalline structure and the mechanism of deformation thus deduced. The general problems are as follows:—

I. IS THE FATIGUE RANGE OF A CRYSTAL OF ALUMINIUM A RANGE OF "PRIMITIVE" ELASTICITY?

Under all ranges of stress investigated, slip bands always resulted from the first applications of stress, however small the magnitude. The limiting fatigue range under reversed direct stresses depends to some extent on the orientation of the crystal, but as the result of experience of a very large number of tests, the *minimum* value of the fatigue range can be evaluated at ± 0.75 tons per square inch, in terms of *resolved shear stress*. If a crystal be stressed at a *safe* range of stress, and its surface examined at various stages, it will be found that the rate of production of fresh slip bands diminishes quickly with repetitions. After a comparatively small number of cycles of stress, no fresh slip will appear, and the specimen will exhibit a state of elastic hysteresis which can persist, apparently, indefinitely. (Some tests have been carried on to a 100 millions reversals without any further slip or other signs of fracture.) Should the applied range of stress exceed the limiting range, then again the rate of production of slip diminishes with repetitions, but *usually* fresh slip is still appearing at the time of actual fracture. Hence, it is apparent that the safe

20. Gough, Hanson & Wright, No. 995, Repts. Mem. Series, Aero. Res. Ctee., Nov. 1924.

21. Gough, Hanson & Wright, Phil. Trans. Roy. Soc. A., Vol. 226, pp. 1-30.

22. Gough, Wright & Hanson, Jour. Inst. Metals, Vol. 36, Pt. 2, 1926.

23. Gough, Wright & Hanson, No. 1022, Repts. Mem. Series, Aero. Res. Ctee., Dec., 1925.

24. Gough, Hanson & Wright, No. 1024, Repts. Mem. Series, Aero. Res. Ctee., Jan. 1926.

25. Gough, Wright & Hanson, No. 1025, Repts. Mem. Series, Aero. Res. Ctee., Jan. 1926.

26. Wright, Phil. Mag.

27. Gough, "The Metallurgist," Sept. 24th, 1926, pp. 132-133.

28. Gough, No. 1110, Repts. Mem. Series, Aero. Res. Ctee., June, 1927.

29. Gough, Trans. Faraday Soc., No. 81, Vol. 24, Pt. 2, Feb. 1928.

30. Gough, Proc. Roy. Soc., Vol. 118, 1928, p. 1.

range of stress is *not* a state of "primitive" but of "acquired" elasticity, as with an aggregate.

2. DO SLIP BANDS REPRESENT THE TRACES OF THE PLANES OF SHEAR ON WHICH THE CRYSTAL IS DEFORMING; IF SO, WHAT ARE THESE PLANES?

The question was first answered from the results of a test on a crystal subjected to reversed direct stresses. Careful measurements were made of the inclination of the slip bands produced (Fig. 35) on all parts of the circumference. It was found that these slip bands corresponded accurately to the traces of one series of parallel planes, and the co-ordinates of this series were calculated. Table I contains the recorded measurements of the slope of the slip bands (as seen in Fig. 35) taken at regular intervals around the complete circumference of the crystal specimen, together with the deviation of each reading from the trace of the mean plane calculated from all the readings. The maximum departure is about 2° only and this includes all experimental errors.

TABLE I.

Angle measured round circumference of specimen from a fixed reference line.	Slope of Slip Bands at point.	Slope of Trace at same point, of Mean Plane calculated from all readings.	Deviation of slope of slip band from that of the trace of the Mean Plane
0°	$41^\circ 50'$	$43^\circ 23'$	$1^\circ 33'$
30°	$48^\circ 13'$	$49^\circ 5'$	$0^\circ 52'$
60°	$45^\circ 17'$	$46^\circ 29'$	$1^\circ 12'$
90°	$36^\circ 17'$	$33^\circ 51'$	$2^\circ 26'$
120°	$5^\circ 9'$	$6^\circ 11'$	$1^\circ 2'$
150°	$— 24^\circ 11'$	$— 25^\circ 48'$	$1^\circ 37'$
180°	$— 45^\circ 22'$	$— 43^\circ 23'$	$1^\circ 59'$
210°	$— 51^\circ 33'$	$— 49^\circ 5'$	$2^\circ 26'$
240°	$—$	$— 46^\circ 29'$	$—$
270°	$— 33^\circ 28'$	$— 33^\circ 51'$	$0^\circ 23'$
300°	$— 4^\circ 31'$	$— 6^\circ 11'$	$1^\circ 40'$
330°	$+ 24^\circ 31'$	$+ 25^\circ 48'$	$1^\circ 17'$

An analysis of the changes in shape of the specimen shewed that the crystal had deformed by a process of simple shear on one set of planes in a particular direction. This plane of shear was in exact agreement with the plane containing the traces of the slip planes, thus establishing for the first time that slip bands

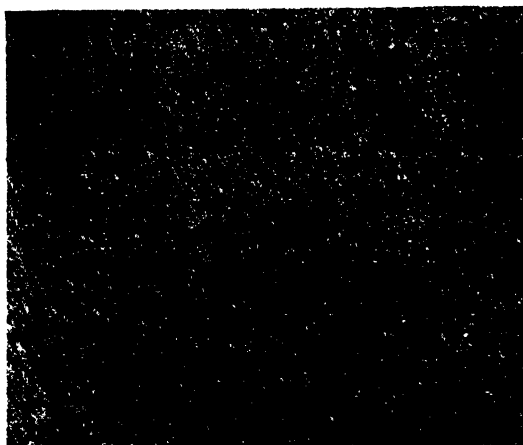


FIG. 35. Slip bands in a single crystal of aluminium, which has been deformed by shear on one set of octahedral planes.

really represent the traces of gliding planes by which deformation proceeds.³² These gliding planes, when correlated to the atomic structure, using the X-ray analysis, proved to be the particular series of octahedral planes containing the primitive direction (110) subjected to maximum resolved shear stress.

3. IS THE MECHANISM OF DEFORMATION OF SINGLE CRYSTALS OF ALUMINIUM UNDER FATIGUE AND OTHER TYPES OF STRESS SYSTEMS SIMILAR TO THAT OF DEFORMATION UNDER STATIC TENSILE STRESS AS PREVIOUSLY DETERMINED BY TAYLOR AND ELAM ?

The stress systems we have investigated include the following :—(a) Reversed direct fatigue stresses, (b) Reversed torsional fatigue stresses, (c) Single blow tensile impact stresses, (d) Deformation under a ball hardness test. A brief word on each of these types :—The cross section of a specimen subjected to various ranges of *reversed direct stresses* changed from a circle to ellipses of various shapes, and an analysis shewed that the deformation was consistent with one of simple shear throughout ; the slip planes were identified always as octahedral planes, *i.e.*, the planes of maximum atomic density. In the first stages, slip proceeded by shear on *one* set of octahedral planes in one of the primitive directions (110) contained by the plane. There are four sets of octahedral planes, each containing three primitive directions, thus offering 12 possible combinations of slip plane and slip direction. The actual slip plane and direction was determined entirely by the condition of maximum resolved

32. NOTE.—The strain markings observed by Mark, Polanyi & Schmid, on crystals of zinc, also agreed approximately with the traces of the planes on which deformation proceeded by shear ; these markings were not, however, ' slip bands ' as usually understood (see original publication), and the exact nature of these markings found on zinc requires (and is receiving at the present time) much more detailed examination.

shear stress. Deformation proceeded on this plane—the relative orientation of the crystallographic and specimen axes changing meanwhile—until, at some stage, two sets of octahedral planes became equally inclined to the axis and equal values of the resolved shear stress in the slip direction on these planes were attained. Further deformation then proceeded by double slipping on both planes. This is precisely the same mechanism of deformation that controls distortion under static tensile loading as found by Taylor & Elam.

The distortion of a single crystal under *torsional* fatigue stresses presents features of apparent great complexity. A glance at the space lattice model (face-centred cubic) shews that a single crystal cannot be twisted by a process of shear on any *one* set of planes without involving discontinuities in the lattice; X-ray analysis has never revealed any such discontinuities. Our work shewed, however, that the deformation under torsion is really the most striking and instructive example of the general law of deformation. It was shewn that the resolved shear stress on any one plane in a certain direction varies, at different positions, round the circumference of a round specimen according to a simple cosine law of the form

$$S_{01} = S A \cos (\lambda - \alpha)$$

where $A = \sqrt{-\frac{1}{2} (\cos 2 \theta_0 + \cos 2 \theta_{01} + 2 \cos 2 \theta_0 \cos 2 \theta_{01})}$

and $\alpha = \tan^{-1} [(\tan^2 \theta_0 - 1) \cot (\Psi_{01} - \Psi_0)] + \Psi_0$

where θ_0, Ψ_0 refer to the plane; θ_{01}, Ψ_{01} refer to the direction and S is the *nominal* maximum shear stress, S_{01} is the value of the shear stress

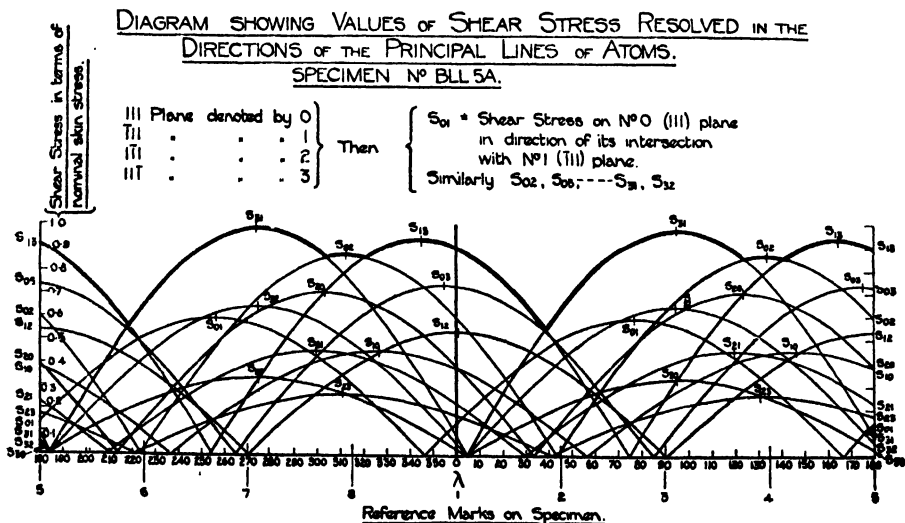


FIG. 36. Results of complete shear stress analysis of a single crystal of aluminium subjected to a torsional couple.

on the given plane resolved in the given direction at any portion on the circumference of the specimen denoted by λ .

Fig. 36 represents the results of a complete shear stress analysis—obtained in this way—of an aluminium crystal used in one of our experiments. The diagram of resolved shear stress on octahedral planes in the contained primitive directions is composed of 12 cosine curves, and we found that the deformation, at any point of the specimen, was determined entirely by the actual maximum value of the resolved stresses at that point, as disclosed by the shear stress analysis. Thus, in the example shewn, slip changes abruptly from one octahedral plane to another similar plane at three points. The next two illustrations shew

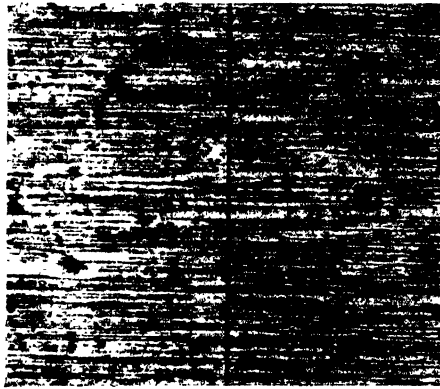


FIG. 37. Slip bands in a single crystal of aluminium due to torsional straining. The position at which this photograph was taken corresponds to the "peak" of the stress curve (S_{31}) of Fig. 36 at the point denoted by $\lambda = 270^\circ$.



FIG. 38. The microstructure at the "change-over" point, in Fig. 36, at the position denoted by $\lambda = 305^\circ$.

two typical features:—(a) the slip occurring on one of the “ peaks ” of the stress curves (Fig. 37), and (b) one of the “ change-over ” points (Figure 38).

I suggest that this typical behaviour of a single crystal under fatigue torsional stressing, where the deformation conforms so exactly to the stress calculation is sufficient to shew that, with the advent of single crystals, a new era of infinite possibilities was opened in the study of the strength of metals ; such calculations are only of an extremely approximate nature when applied to crystalline aggregates.

The deformation and fracture of a single crystal under single blow tensile impact was also studied. An examination of the slip bands formed, the change in shape of the cross section of the specimen, and the changes in relative orientation of the specimen and crystallographic axes, shewed that the mechanism of deformation was of precisely the same general type as that occurring under direct fatigue stresses.

Attention was also given to the distortion of a single crystal in the neighbourhood of a ball impression. The slip bands were found to correspond exactly with the traces of octahedral planes.

Therefore, the answer to our enquiry is that the mechanism of deformation under static, fatigue and impact stressing is of precisely the same nature, namely, by a process of slip or shear on octahedral planes in one of the primitive directions. I may add that experiments, now in hand, on deformation under combined static and fatigue stresses, shew that the same simple law controls the deformation.

4. UNDER A SAFE RANGE OF STRESS, A SINGLE CRYSTAL OF ALUMINIUM DEFORMS PLASTICALLY AND, AT SOME LATER STAGE, BECOMES “HARDENED” SO AS TO BE ABLE TO RESIST FURTHER CYCLES OF STRESS WITHOUT FURTHER DEFORMATION. WHAT ARE THE RELATIVE STRESS MAGNITUDES ON THE SLIP PLANE BEFORE AND AFTER SLIP, OR, IN OTHER WORDS, IS THE HARDENING AN APPARENT EFFECT ONLY (DUE TO STRESS REDISTRIBUTION) OR A REAL EFFECT ?

This is easily answered. Consider a specimen subjected to a constant range of direct load, P . Denote the area of the slip plane by A , and the inclination of the *direction of slip* to the line of loading by θ^1 . Let the slipping be confined to the one set of parallel planes. Then the value of the resolved shear stress in the slip direction is simply :—

$$f_s = \frac{P}{A} \cos \theta^1$$

It has been shewn previously that the area of the slip plane remains constant, also, that the axis of the specimen tends to approach the direction of slip. Hence θ^1 diminishes and $\cos \theta^1$ increases. Hence the shear stress tending to produce further slip increases with slip and yet the amount of slip is limited. Thus not only is hardening of the slip plane during fatigue stressing a real

effect, but it must be completed simultaneously with the slipping action producing the hardening, otherwise slipping, once commenced, would continue until fracture supervened."³³

5. THE HARDENING OF A SINGLE CRYSTAL DUE TO PLASTIC DEFORMATION HAVING BEEN ESTABLISHED, IS THIS HARDENING CONFINED TO PLANES OF SLIP, OR IS THE METAL HARDENED THROUGHOUT; ALSO, DOES THE SAFE RANGE OF STRESS REPRESENT THE LIMIT OF HARDENING?

Consider a single crystal of aluminium subjected to a statical tensile test. (Fig. 39)³⁴ Prior to the test an X-ray analysis is made of the specimen; the latter is then strained. The elongation at various stages of the test, also the corresponding loads, are recorded, also the initial cross sectional area of the specimen. With these data the changes in shape of the specimen, the areas of the octahedral planes and the values of the resolved shear stress on each of these planes in the contained primitive directions can all be calculated with the aid of a stereographic net. For brevity, the various sets of octahedral planes are termed 0, 1, 2 and 3. The lower diagram shews the changes in the areas of these planes (the inset diagram being to a smaller scale). The upper diagram shews the variation in the value of the resolved shear stresses on the four sets of planes in the twelve possible slip directions. Thus S_{01} indicates the value of the resolved shear stress on the 0 plane in the direction of its intersection with the 1 plane, etc. *The slope of each curve* defines the lower limit of the rate of hardening and, for the actual slip plane, S_{11} , this has a maximum value at the *commencement* of the extension. It is seen that the shear stress, S_{23} , is, on the whole, increasing at a greater rate than S_{11} , and at 59% extension the two values become equal, two sets of octahedral planes being now equally inclined to the specimen axis. Now it is clear that the actual slip plane has become hardened. If the competing slip plane has not become equally hardened (although deformation has not yet taken place on this plane) slip would occur much more readily on the second plane. But in actual tests on many crystals it is usually found that not until the resolved shear stress on the second plane *exceeds* that on the original slip plane does slip occur on the former. It is, therefore, clear that slip on one plane results in a mass hardening of the material. It appears to me that these experimental facts throw considerable doubt on the hypothesis that layers of hard amorphous material formed on slip planes are responsible for increased hardness; it seems reasonable to suppose, if this were true, that the resistance to shear in directions parallel to and transverse to such hard layers would differ greatly. It is important to note that when slip commences on the competing slip planes, none

33. NOTE.—A complete analysis of the resolved shear stresses during a fatigue test will be found in Phil. Trans. Roy. Soc. A., Vol. 226, pp. 1-30. (Gough, Hanson & Wright).

34. NOTE.—This diagram (prepared especially for the present lecture) has been calculated from the records—load, strain and X-ray analysis—of a tensile test of a large single crystal of aluminium.

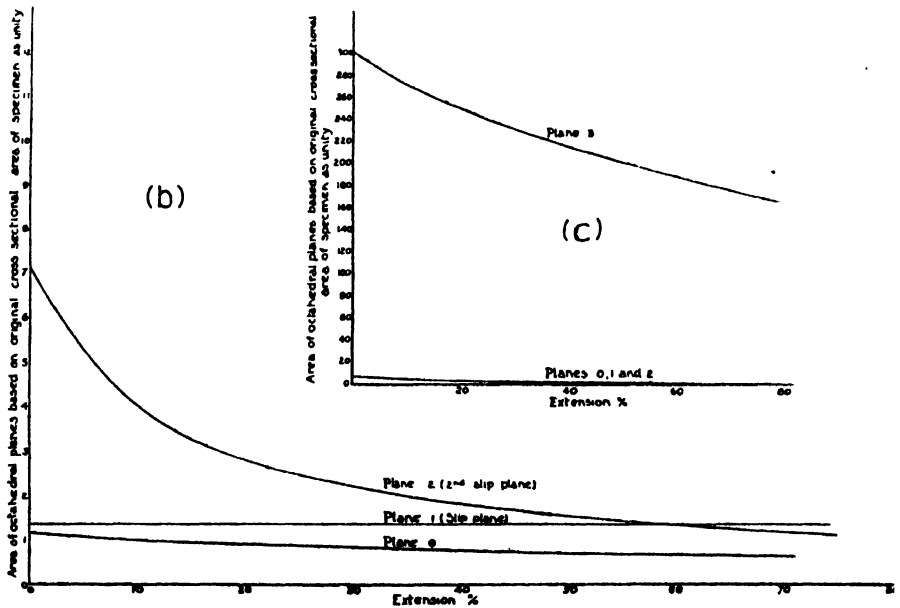
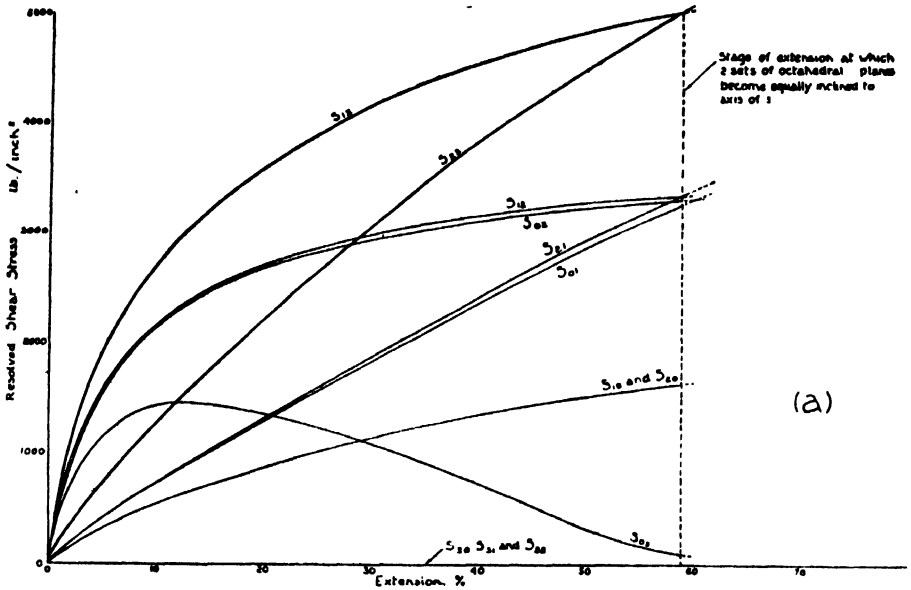


FIG. 39. Diagram of Resolved Shear Stress on octahedral planes during a Static Tensile Test on a single crystal of aluminium during that stage of the test in which slip is confined entirely to one set of octahedral planes.

of these planes contain precisely the same particles which formed the plane before the crystal was deformed. (This is easily demonstrated by assembling a pile of pennies and marking any plane inclined to the plane of the surfaces of the coins. After deformation has proceeded by shear on the interfaces of the coins, the several portions of the marked plane are now translated relatively to each other). This would be immaterial if the process of slip was merely a transfer of atomic bonds without involving lattice distortion (either permanent or elastic), but such is not the case; hence, the observed general hardening of the material due to slip on one set of parallel planes only is a result that might be expected and is certainly easily comprehended. To demonstrate the proof that the slip plane is actually hardened, the simple case of static tensile strain has been chosen; precisely the same action occurs in a fatigue test, and the complete stress analysis of a crystal under fatigue stresses will be found in our papers^{20, 21}, on crystals.

The relation of the fatigue range to the limit of hardening of the material raises a fundamental issue; we have attacked this problem employing two distinct methods, ball hardness tests and the production of slip bands. A single crystal was fractured under cycles of a range of reversed torsional stresses, which greatly exceeded the safe range. The stress analysis and the observed slip bands shewed that the crystal deformed by slip on two sets of octahedral planes in the direction of their common intersection. After test the specimen was cut along a plane perpendicular to the axis, the cross section was polished, and on it a series of ball indentations was made. A table²² was prepared stating the relative hardness at various positions expressed in terms of the hardness at the centre of the specimen. It was found that the hardness value at any point was roughly proportional to the stress intensity at that point. As these stresses varied from zero to a value exceeding the safe range, it was thus proved that the safe range does not mark that stage at which the hardening of the metal, as a whole, by plastic deformation, reaches a maximum. But all our experience has shewn that fatigue cracks first become visible in those regions which have suffered maximum plastic distortion, as evinced by the intensity of the slip band markings. It therefore appears to be most probable that fatigue cracks occur as an *indirect consequence* of previous distortion by slip. Now, if hardening results in severe lattice distortion in local regions, an applied system of alternating stresses might produce principal stresses of such an intense nature as, conceivably, to initiate small sub-microscopic cracks and cause their propagation without further plastic deformation. If this could happen, it should be possible to harden up a crystal specimen—by cycles of a range of stress slightly exceeding the safe range—to such an extent that the last stages of fracture would consist merely of a joining up of sub-microscopical cracks, or the spreading of cracks due to stress concentration effects; in either case, principal stress would be the agent, and *slip bands would not*,

necessarily, be produced. To investigate this, experimentally²³, a crystal specimen was tested under alternating torsional stresses whose value was slightly greater than the safe range. Slip occurred on *three* sets of octahedral planes. The specimen was examined, photographed and re-polished at seven stages of the test. It was found that the process of progressive hardening was in action throughout, as revealed clearly by the decrease in the areas of visible slip. After seven million reversals the specimen was completely hardened under the applied range and no further slip bands were produced; no signs of any cracks could be detected at this stage. The specimen fractured after a further two million reversals and no slip bands whatever could be seen in the neighbourhood of the fracture. *Evidently, the propagation of the fracture had occurred without visible slip.* -

6. DURING FATIGUE OF A FINELY DIVIDED CRYSTALLINE AGGREGATE HOW IS THE BEHAVIOUR AFFECTED BY THE PRESENCE OF THE INTERCRYSTALLINE BOUNDARIES ?

Metals, as ordinarily used in engineering construction, consist of a large number of small crystals, of differing orientations and whose size is usually such that one cubic inch of the metal will contain a million or more crystals. We hope, eventually, to estimate the effect of the boundaries by successive studies, first, of the fatigue properties of large single crystals, then of specimens consisting of two, four and increasingly greater numbers of crystals. Little has yet been accomplished but two results possess some interest. In one experiment, a specimen consisting of three large crystals was fatigued under alternating torsion. In general, the slip bands observed were similar in all respects to those observed in single crystals. Where two neighbouring crystals did not differ appreciably in orientation the slip bands continued, in most cases, right up to the boundary. At the junctions of crystals of differing orientations, a "shielding" effect was noticed, the majority of the slip bands stopping short of the boundary. The fracture was entirely trans-crystalline and where it spread into neighbouring crystals it intersected the boundaries nearly at right angles. (Fig. 40). This experiment was of a preliminary nature only, but it indicated that the differences between the behaviour of the specimens and of a single crystal were principally due to the differing orientations of the constituent crystals rather than to any particular property of the boundary as an entity. The second series of tests was made to investigate the effect of repeated stresses on the density of aluminium. Specimens consisting entirely of a single crystal were tested first.²⁴ Nine specimens were tested under reversals of direct stress; some ranges were safe (specimens withstood up to 60 millions of reversals and remained unbroken) others fractured at various endurances. The density of each specimen was determined before and after test using methods of highest possible precision. The results were as follows:—

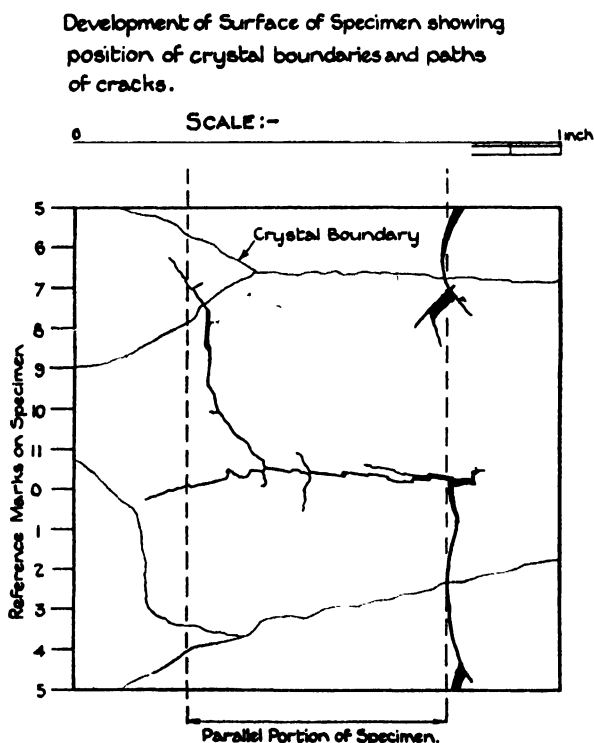


FIG. 40. Showing the position of the fatigue cracks in relation to the crystalline boundaries in an aluminium specimen, consisting of three large crystals.

- (a) Density before test 2.7054 $\left(\begin{array}{l} + 1/3865 \\ - 1/3385 \end{array} \right)$
- (b) Density after test 2.7056 $\left(\begin{array}{l} + 1/4509 \\ - 1/3006 \end{array} \right)$

As the guaranteed order of accuracy of the density determination was 1 part in 3,000, the results shew that no change in density was detected that can be attributable to the fatigue history of the specimens. A similar series of experiments was then made²⁸ on polycrystalline material of the same batch from which the single crystals had been prepared. It was given a similar annealing treatment to that undergone by the single crystals. Fatigue stressing under reversed direct stresses was again employed. The results shewed that definite decreases in density resulted from the stresses, the amount varying from 0.037% up to maximum of 0.100%. This decrease can only be ascribed to the presence of the boundaries. O'Neill²⁷ has studied the effect of cold work on the density of iron aggregates and on a single crystal of iron, and found that the density of the single crystal was unaltered, while a marked decrease in density occurred

in the aggregate. Owen & Preston³⁸ have studied the density of severely cold-rolled aluminium aggregate. They found no change in density. Remembering that the operation of rolling must produce conditions approximating to those of hydrostatic pressure as compared with the simple deformation produced by tension, compression, or alternating stresses, all these results suggest that the effects leading to changes of density due to cold work have either their origin at, or in the neighbourhood of, crystal boundaries, and are probably due merely to discontinuities produced by the unequal degrees of deformation taking place on opposite sides of such boundaries.

7. IS THE BEHAVIOUR OF A STRESSED SINGLE CRYSTAL CONSISTENT WITH THE EXPECTED BEHAVIOUR OF AN IDEAL CRYSTAL POSSESSING PERFECT REGULARITY OF CRYSTALLINE STRUCTURE ?

In the absence of any precise knowledge regarding the nature and amount of the inter-atomic forces, the behaviour of a perfect single crystal under stress becomes highly speculative. Nevertheless, if we make certain reasonable assumptions some idea can be gained of this probable behaviour. Let us assume that the inter-atomic forces vary as some inverse function of the inter-atomic distances. Then, in the case of face-centred structures, we should expect deformation to proceed by a process of shear on the planes of greatest atomic density in a primitive direction. If the method of straining consisted in applying shearing *forces* of increasing intensity, the resulting *strains* not being controlled in any way, the crystal would be expected to possess an appreciable range of elasticity, followed by plastic extension of an indefinitely great amount. Each potential slip plane would be expected to enter to an equal degree into the deformation. With microscopes possessing the present limited degree of resolution, slip bands should not be *visible*, neither would it be possible to obtain small permanent extensions which are *less* than that equivalent to the summation of unit slip on each slip plane. (This corresponds to an angle of shear of, approximately, 51° , equivalent to $58\frac{1}{2}\%$ extension in an aluminium crystal whose most highly stressed octahedral plane had a θ value of 45°). Hardening effects would *not* be expected. In actual tests we find that our "single" crystals of aluminium possess *no appreciable range* of primitive elasticity under static or fatigue stressing; also we can produce permanent extensions varying from a very small amount upwards at will. Further, under a small range of stress, visible slip bands of an approximately uniform pitch are obtained; under higher ranges, we find slip bands of a smaller pitch. Finally, marked hardening effects occur under *all* ranges of stress. From these facts we infer that our "single" crystals are *not* perfect, that all parallel slip planes are not of equal strength, and that the crystal is apparently composed of regular series of strata of varying resistance to deformation by shear, each series probably possessing approximately equal strength. Further, as the observed slip bands are not continuous, it appears probable that local differences of strength exist on any particular slip plane.

SECTION XI.

PRESENT POSITION OF THE THEORY OF THE SUBJECT.

Many theories of fatigue have been suggested ; some of these are obviously incorrect, others are of such an indefinite nature that the acid test of experiment cannot be applied to them. Now as metals in their simplest form—the single crystal—are subjected to fatigue, it is apparent that any comprehensive theory must explain the fatigue phenomena of single crystals. In view of the fact that the quantitative studies of the behaviour of metallic crystals under static and fatigue stressing have all been made during the last five and one-half years only, and that some of the phenomena encountered were entirely unexpected, it is not surprising to find that a fundamental theory of fatigue has yet to be developed. There is no reason for pessimism over this fact, as it indicates a recognition that with the research appliances now available, it ought to be possible in time to evolve a quantitative fundamental theory relating to the atomic structure itself and that a less fundamental theory is neither acceptable nor desirable. In other words, it is now recognised that fatigue failure is merely a special case of the general problem of the cohesion of matter and must be treated as such in a perfectly general manner. Further, it is now becoming apparent that if a complete understanding can be obtained of three main phenomena, namely the cause of the low initial strength of crystals and the mechanism and consequences of slip and of strain hardening, then the main problems of fatigue will have been solved.

In 1920, Griffith³⁹ shewed that the observed strengths of brittle substances, such as quartz and various glasses, represented only fractions of their calculated strengths, and in support of his suggestion that the discrepancy was due to stress concentration effects caused by the presence of minute flaws in the material, actually prepared fibres of these materials whose strengths closely approached the theoretical values. This is the theory of internal flaws. There is a difficulty in applying this theory to ductile metals, as the latter fail by shear, and it is impossible, at present, to estimate the theoretical resistance. But we have seen that the actual behaviour of single metallic crystals indicates clearly that their observed strengths are absurdly low and the internal flaw theory is most probably applicable even to ductile metals, and is, in fact, obtaining increasing acceptance. Moreover, natural crystalline substances, such as rock salt, exhibit similar differences between theoretical and actual strength as the vitreous substances examined by Griffith. On the other hand, minute *surface* defects have been held responsible ; this point of view is due mainly to Joffé.⁴⁰ In support of the “ surface defect ” theory as against the “ internal flaw ” theory, Joffé shewed that spheres of rock salt when cooled to liquid air temperature followed by immersion in molten lead withstood

39. Phil. Trans. Roy. Soc., 1920, 221, A, 163.

40. Zeit. fur. Physik, 1925, 31, 576.

successfully an estimated core stress (hydrostatic tension) of about 40 tons per square inch, the ordinary tensile strength of rock salt being less than 0.5 ton per square inch. This is cited as evidence against the internal flaw theory. Also, rock salt crystals, when bent under water, develop estimated strengths of approximately 100 tons per square inch; the increase is attributed to the removal of the surface material by solution.⁴¹ However, Polanyi & Eweld⁴² have shewn that this effect is *not* due to the removal of surface layers, as rock salt, if immersed in water and subsequently dried and tested, shews *no* increase in strength; further, rock salt crystals strained plastically under water and subsequently dried and tested in air, exhibited strain-hardening effects. The hardening found by Joffé may, therefore, be ascribed to the increased plasticity of wet rock salt and this has been demonstrated experimentally. No explanation has yet been offered of the cause of the increased plasticity. These enquiries appear to lead, therefore, to an *impasse*. Let us explore various suggestions arising from the phenomena of strained metals as exhibited by X-rays.

If a beam of X-rays is passed through an unstrained natural or metallic crystal, a pattern is received on a photographic plate which consists of a number of sharply-defined spots arranged in a definite geometrical pattern. After permanent distortion of the crystal, these spots become elongated and are known as "Asterism striations." This phenomenon, first noted by Rinne in 1913, as occurring in mica, was later studied by Czochralski⁴³ for single crystals of aluminium and gypsum. Similar effects are observed in aluminium single crystals after fatigue stressing. We have obtained⁴⁴ such a Laue diagram from one of our specimens after cycles of reversed direct stresses. Now, such an effect can be ascribed to several causes:—

(a) The lattice structure may have become entirely broken down in certain directions, producing what may be called amorphous material, (b) the crystal may have broken up into a large number of small fragments, each of which has rotated slightly from its original position—this we will term fragmentation—or (c) to the presence of residual elastic stresses in the lattice due to bending of the slip planes—this is what we will term lattice distortion, or (d) to a combination of (a), (b) and (c). Czochralski considered the amorphous theory to have been completely disproved for other reasons—he says "in Germany the amorphous theory has been completely and justifiably rejected";—yet he concludes that the crystalline structure has been completely broken down. (This differentiation appears to me to be somewhat curious because, in this country, Czochralski's "broken-down structure" is identical with the picture of amorphous material resulting from polishing processes, etc., as pictured

41. Zeit. fur. Physik, 1925, 31, 576.

42. See: Trans. Fara. Soc. Vol. XXIV, pt. 2, Feb. 1928, pp. 167/168.

43. Zeit. fur. Metallkunde, 15, 60, 1923.

44. Gough, Wright & Hanson.

(a) No. 995, Repts. Memo. Series, Aero. Res. Ctee., Nov. 1924.

(b) Phil. Trans. Roy. Soc. A., Vol. 226, pp. 1-30.

by those adhering to the Beilby idea ; at any rate, as I understand it.) Czochochalski did not consider that the observed asterisms were consistent with "fragmentation ;" he based this belief upon the fact that Laue diagrams⁴⁵ taken from specimens in which the number of grains, in the X-ray beam, varied from one to a million, merely shewed duplication of spots without distortion. In fairness to Czochochalski, it must be clearly stated that the possibility of fragmentation was fully realised by him ; he says, " a necessary condition of such an arrangement of the structural elements is that countless clefts would have to run through the crystal thus transformed and this is unlikely since the crystal would thereby lose a great deal of strength. But the strength of stressed crystals as a rule is greater than that of unstressed crystals." He appears to have overlooked the possibility that the clefts may have existed initially producing slip, rotation of fragments and a consequent *hardening*.

The next great step was made by Goucher.⁴⁶ He cut sections of deformed tungsten single crystals along the slip plane and examined the nature of the X-ray reflections obtained from these surfaces. He shewed that considerable distortion occurred in the *direction of slip*, but that sharp reflections were obtained at right angles to this direction. Thus the distortion was equivalent to a bending in the direction of slip. Now if these effects were purely elastic, an atomic displacement of at least 10% was involved, whereas X-ray measurements of a high order of accuracy failed to reveal any change in lattice parameter. Hence, the only possible interpretation of this important work was that fragmentation had occurred, the crystal fragments arranging themselves on curved planes within the crystal. Considerable elastic strains must be set up at the junctions of the crystallites. About the same time (1924) my colleagues and I had come to very similar conclusions about our crystals after subjection to fatigue stresses, with one important difference. The X-ray analysis of deformed crystals (determined during a complete rotation of the specimen) shewed that the *mean curvature* of the slip plane was zero, but the presence of asterism striations indicated that the planes of slip had become buckled.

Further, some intensity measurements made by our colleague, Mr. Preston, suggested to us that the shape of the slip plane after deformation was similar to that of corrugated cardboard (the line of corrugation being at right angles to the slip direction), involving either regions of elastic strain, or duplex fragmentation accompanied by elastic strains at the junctions of crystallites. On that assumption we suggested a theory of fatigue⁴⁶ which offered a satisfactory explanation of the more important fatigue phenomena. On one vitally important point, however, we could offer no explanation ; it related to the mechanism and cause by which the crystallites rotated if actual fragmentation occurred. Further, if the rotation involved only elastic strains

45. Phil. Mag., Vol. XLVIII, Nov. 1924.

46. Gough, Wright & Hanson, No. 995, Repts. & Mem. Series, Aero. Res. Ctee., Nov. 1924.

it was not apparent why the final position was more stable than the initial state (we know that it *is* more stable because if the strain-hardened crystal is softened by annealing, the asterisms do not disappear). I believe that this point has now been cleared up satisfactorily by Professor Taylor. In a recent very important paper,⁴⁷ he considers the consequences arising from the presence of small discontinuities on the slip planes. Applying the theory of elasticity he found that the stress concentration set up at the ends of the cracks would tend to make the material rotate about an axis perpendicular to the direction of slip; this is therefore exactly in accordance with the X-ray phenomena exhibited by a strained single crystal. Also, the rotation caused by the presence of an initial crack is shewn to produce other cracks whose stress concentration effects are relatively smaller; this is consistent with observed hardening effects and the shape of the experimental stress-strain curve. In some previous work, Farren & Taylor⁴⁸ found that when metals are strained plastically the energy applied by the external straining forces is in excess of that evolved in the form of heat during the operation; moreover, that the ratio of the energy absorbed to the heat dissipated was a constant relation for differing stages of the deformation. Professor Taylor now finds that this constancy of ratio is predicted from the new consideration of the effects of small initial flaws in the crystalline structure.

Much experimental work requires to be accomplished and is being actively pursued. I trust, however, this brief account of recent work has been sufficient to shew that, although in order to approach the mechanism of failure of engineering objects such as crankshafts, gear wheels, turbine discs, etc., etc., by a study of the behaviour of plastic single crystals may seem an academic and indirect route, yet the path may be the shortest in the end, leading to the desired goal, *i.e.*, a fundamental knowledge of fatigue phenomena.

In conclusion, I would express my appreciation of the honour conferred on me by the invitation to deliver these Cantor Lectures. In presenting this subject I have purposely made no attempt to render the subject matter in a "popular" style, but have aimed at giving a concise outline of the main characteristics of fatigue phenomena, including the results of very recent researches, thus presenting a critical summary of present knowledge. I have many acknowledgments to make; to Messrs. Ernest Benn for their most generous permission to make the fullest use of data and blocks taken from my book on "Fatigue"; to the American investigators of fatigue problems, notably Professors Moore, Kommers and Jasper, Dr. McAdam, and Messrs. R. R. Moore, Timoshenko and Lessels, for their kindness in keeping me in close touch with their researches and a very helpful correspondence extending over some years; to Dr. McAdam, Professor Lea, Professor Haigh, Mr. Tapsell and

47. "Resistance to Shear in Metal Crystals," G. I. Taylor, Trans. Faraday Soc., Vol. XXIV, Pt. 2, Feb. 1928.

48. Proc. Roy. Soc. A., Vol. 107, 1925, p. 422.

Mr. R. R. Moore, for permission to reproduce certain diagrams illustrating their researches; to the Royal Society for permission to reproduce certain illustrations from the Proceedings and for the generous loan of blocks; to the Engineering Research Board, who have financed most of the recent researches on Fatigue undertaken at the National Physical Laboratory; and, finally, to Sir Thomas E. Stanton, in whose laboratory many of these researches have been carried out, and for whose interest and encouragement in research work my colleagues and I can never be sufficiently grateful.

NOTES ON BOOKS.

THE ORIGIN AND DEVELOPMENT OF THE MICROSCOPE, as illustrated by catalogues of the Instruments and Accessories in the Collections of the Royal Microscopical Society, together with bibliographies of original authorities. Edited by Alfred N. Disney, M.A., B.Sc., F.R.M.S., in collaboration with Cyril F. Hill, M.Inst. M.M., A. Inst.P., F.R.M.S., and Wilfred E. Watson Baker, A.Inst.P., F.R.M.S.: preceded by an historical survey of the early progress of optical science by the Editor. London: the Royal Microscopical Society, 1928.

There are certain fields of instrument design in which the operation of "evolution" through a kind of "natural selection" is admirably illustrated. Such a field is that of the microscope; another of more recent activity is the range-finder. No designer of either instrument would give himself a fair chance of making any improvement in his work unless he were possessed of some knowledge at least of the main lines of development.

So diverse are the modern uses of the microscope that even if the maker be, like the famous Benjamin Martin at "The Sign of the Globe and Visual Glasses" in Fleet Street, a microscopist who can use his instrument intelligently and with affection, he can hardly make himself acquainted with all the technical requirements of practice; he must be guided to a great extent by the consensus of opinion of users. There are many and various expedients which have been tried and found wanting; some measure of agreement has been reached, and it is unlikely that the main characteristics of modern designs will ever be abandoned in instruments primarily intended for visual observation.

What are the motives of historical research in such a subject? Surely the main one is that of sheer joy in human achievement and its progress: the amazing skill of these old-time craftsmen with their crude appliances: the quieter and simpler life of the workshop where mass production was a thing unthought of. In the study of the works of the early thinkers we can recapture the inimitable delight of a glimpse of slowly-emerging truth; our experience is wonderfully enlarged and our own work takes on a new significance and value as it is seen in relation to all the doings of other days.

The R.M.S. collection of instruments comprises examples dating from about A.D. 1673 and onwards; the development of optical science before this period is dealt with in Part I of the book, occupying (with its admirable bibliography) about half of the volume, and is perhaps the most thorough and complete separate account of the origins of instrumental optics which is available in English. The somewhat confusing evidence as to the invention of the telescope and microscope is clearly set out. It is unfortunate that these uncertainties exist, but even if there are

grounds for setting forth the pros and cons in this matter, we see no clear ground for discussing the story of the destruction of a Roman *fleet* by Archimedes with a burning mirror.

Considerable pains are taken in this section to rebut the supposition that such optical instruments as hand-magnifiers and perhaps telescopes were used by the ancients.

Part II of the book comprises a well-illustrated and descriptive catalogue of the actual instruments and accessories in the Society's collection, commencing with the copy of van Leeuwenhoek's simple microscope (*circa* 1673) and ending with outstanding nineteenth century designs. The list is accompanied by a bibliography referring to contemporary books in the Society's library, and by a series of excellent plates. Here we trace the early development of a variety of types, the disappearance of the tripod form with its central vertical tube and the emergence of the optical bench type.

Food for thought will be found in the early introduction of a wide body tube, its abandonment in later times, and its re-introduction in recent years. Those who care to go more deeply into an interesting piece of research which has at present few, if any, workers in its field might study the mutual influence of workshop practice and instrument construction. Was it Joshua Lover Martin who invented the art of drawing brass tubing on a mandril towards the end of the 18th century? This development alone was surely capable of exercising a profound influence on instrument construction.

It is a matter for some regret that fuller details of the optical systems of the catalogued instruments are not given. It is difficult to gather from the descriptions what modifications in the design of the stands arose from the gradual introduction of achromatic lenses for the microscope in the early part of the nineteenth century, with their consequent requirements of increased rigidity and accuracy.

It would be of the greatest interest and utility if the collection could be used to illustrate the development of optical design through the single lenses, achromatic doublets, Lister type objectives, and immersion objectives which was witnessed during the last century. Surely this invaluable work is not outside the range of possibility, as the designs of many objectives must still be available from optical firms still extant, and thus the lenses in the microscopes need not be pulled to pieces to ascertain their construction. We insist on this point because, after all, the mechanical part is *but* a part of a microscope, even if the most obvious part.

This collection and catalogue is at once a delight and a challenge. We need not remind the Fellows of the Royal Microscopical Society that microscopical history is still being made, and the application of the instrument is being extended into wider fields where originality and resource is still called for. In our opinion every effort should be made to keep this important collection up-to-date and from now on to record the fullest details not only in regard to mechanical construction, but also in regard to materials and optical systems.

We consider that the Society is in this volume doing a very real service to the cause of science.

L. C. MARTIN.

QUESTIONS AND ANSWERS ON TYPEWRITING AND OFFICE PROCEDURE. By Arthur E. Morton. London: Sir Isaac Pitman and Sons, Ltd. 7s. 6d.

The author of this work is generally recognised as one of our highest authorities on typewriting. He began his career as a shorthand-typist nearly fifty years ago, and he has had practical experience of thirty-six different kinds of typewriter

What he does not know about machines, past and present, is, therefore, not knowledge, and his sections on the history and development of the typewriter are full of interest. Unfortunately, however, these form but a small portion of the book, the bulk of which consists of two parts, one containing 750 questions and the other containing the answers to those questions. From the point of view of the student working for an examination, this arrangement is perhaps satisfactory, but no one can claim that it tends to make the book readable.

It need hardly be said that, composed as they are by a man of Mr. Morton's experience, the answers contain a great deal of useful information. Indeed, anyone who has mastered them need fear no examination in the "theoretical" side of typewriting. We venture to think, however, that a number of the questions might well have been omitted. Mr. Morton thinks, and quite rightly, that the only foundation upon which a typist can excel is a sound knowledge of spelling, punctuation and grammar. But are spelling, punctuation and grammar functions of typewriting? Should a candidate's knowledge of them not rather be tested by an examination in English? And do not the ideas of English entertained by a typewriting examiner sometimes leave something to be desired? In answer 746, for instance, Mr. Morton writes: "The main desiderata is neatness and simplicity"; and in question 723 he tells the student to correct any mistakes he may observe in the following sentence:—"The girl of ideas is the girl who succeeds." Turning with wonder to the answer to this conundrum we find the author prefers, "The girl of ideas is the one who succeeds." Another extraordinary question is No. 337: "State the official designations of the heads of colleges in the following Universities and explain how you would address them," and then are given the names of all the colleges in Oxford and Cambridge. We doubt if any one in the world could answer this question unless he had made a special study of it, and what on earth would be the use of committing these titles to memory when they can all be found conveniently tabulated in *Whitaker*?

The questions dealing with typewriting proper strike us as being extremely practical and comprehensive, and if, as seem likely, a second edition of the book is called for, we hope that the author will confine himself to his last and cut out questions of the kind that we have been criticising as well as his "missing word competitions."

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, OCTOBER 8. Automobile Engineers, Institution of, at the Merchant Venturers' Technical College, Bristol. 6.45 p.m. Mr. Leslie H. Hounsfield, Presidential Address, "The Integrity of the Technical Man."
Brewing, Institute of, at Charing Cross Station Hotel, Strand, W.C. 7.45 p.m. Messrs. F. W. Cooke, A. Hadley and H. Lloyd Hind, "The Season's Malts (made from 1927 Barleys)."
Metals, Institute of, at 30, Elmbank Crescent, Glasgow, 7.30 p.m. Mr. S. E. Flack, Chairman's Address.
TUESDAY, OCTOBER 9. Metals, Institute of, at Armstrong College, Newcastle-on-Tyne. 7.30 p.m. Dr. J. A. Smythe, Chairman's Address.
Arts, Royal Academy of, Burlington House, W. 4.30 p.m. Professor Arthur Thomson, "Anatomy." (Lecture III).
Heating and Ventilating Engineers, at Caxton Hall, Brodway, Westminster, S.W. 6.45 p.m. Dr. H. M. Vernon, "Methods of Heating and Ventilating Schools and their Influence on Health."
Petroleum Technologists, Institution of, at the Royal Society of Arts, Adelphi, W.C. 5.30 p.m. Dr. F. H. Garner, "The Analysis of Cracked Spirit—The

Determination of Aromatic Olefine, Napthene and Paraffin Hydrocarbons."

WEDNESDAY, OCTOBER 10. Fuel, Institute of, at Burlington House, Piccadilly, W. 6 p.m. Mr. T. A. Peebles, "Automatic Combustion Control of Liquid, Solid and Gaseous Fuels for All Purposes." At Thomas' Café, Swansea. 7 p.m. Mr. J. H. Grant, Chairman's Address.

University of London, at Bedford College for Women, Regent's Park, N.W. 5.15 p.m. Miss S. M. Fry, "Penal Reform." At the School of Oriental Studies, Finsbury Circus, E.C. 5.15 p.m. Mr. S. Topalian, "Wit and Wisdom in Turkish Literature."

THURSDAY, OCTOBER 11. Mechanical Engineers, Institution of, at the Hotel Metropole, Leeds. 7.30 p.m. Mr. W. H. Poole, "Modern Foundry Practice and the Engineer."

Metals, Institute of, at 83, Pall Mall, S.W. 7.30 p.m. Dr. S. W. Smith, Chairman's Address.

FRIDAY, OCTOBER 12. Arts, Royal Academy of, Burlington House, W. 4.30 p.m. "Anatomy" (Lecture IV).

Metals, Institute of, at the Applied Science Department, University of Sheffield. 7.30 p.m. Mr. R. D. Barklie, "Alternating Current Electrolysis": Dr. E. B. Sanigar, "Sodium Cyanide in Silver Plating."

SATURDAY, OCTOBER 13. L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Professor J. R. Ainsworth Davis, "The Animal Conquest of the Sea."

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FRIDAY, OCTOBER 12th, 1928.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICE.

SWINEY PRIZE.

The Council give notice that the next award of the Swiney prize will be in January, 1929, the eighty-fifth anniversary of the testator's death. Dr. Swiney died in 1844, and in his will he left the sum of £5,000 Consols to the Royal Society of Arts, for the purpose of presenting a prize, on every fifth anniversary of his death, to the author of the best published work on Jurisprudence. The prize is a cup, value £100, and money to the same amount.

The award is made jointly by the Royal Society of Arts and the Royal College of Physicians. In accordance with the arrangement with the Royal College of Physicians, the award next year will be for a work on Medical Jurisprudence.

Any person desiring to submit a work in competition, or to recommend any work for the consideration of the judges, should do so by letter, addressed to the Secretary of the Society, not later than November 30th, 1928.

A list of former recipients of the prize was given in the *Journal* dated March 23rd.

CANTOR LECTURES.

The Cantor Lectures on "The Scientific Foundations of the Refining of Petroleum," by Dr. A. E. Dunstan, D.Sc.(London), F.I.C., F.C.S., are available in pamphlet form (price 3s.), and can be obtained from the Secretary, Royal Society of Arts, John Street, Adelphi, W.C.2.

A complete list of Cantor, Howard and other lectures, which are available in pamphlet form, can also be had on application.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

ACOUSTICS.

By A. G. HUNTLEY (of the May Construction Co., Ltd.).

I.

(Delivered 16th April, 1928.)

In opening this series of lectures, perhaps a word or two may not be out of place on their scope and the lines they are to follow. Architectural Acoustics is a subject which is at once both ancient and modern, though, perhaps, it would be more precise to say that the appreciation of the effect is ancient whilst the knowledge of the causes is modern. From the earliest time, echo—the best known of all acoustical phenomena—has been commented on and has alternatively been worshipped as a god or propitiated as a devil, and, even to-day, is reported to be still holding sway among the deities of certain South Sea Islanders. Children, too, take a delight in making it exercise its vagaries or listening to the apparent intensification of their youthful voices under the arch of a bridge. Again, who, amongst the male population, has not felt a glow of self-satisfaction and pride at his apparently rich and mellow voice when exercised in the confines of the bath room, and has not my lady often remarked on “the funny ring this empty room seems to have?”

Thus, even from our youth up, we have been rubbing shoulders with one or other acoustical phenomenon, and yet if we were asked casually about echo, we should probably say, “Echo—echo, ah! yes, the Albert Hall or St. Paul’s Cathedral.” The very mention of the subject automatically seems to conjure up a mental picture of large and lofty buildings, of concert halls, theatres and cathedrals, and we entirely lose sight of the fact that it certainly has as large, if not indeed a larger, field in those buildings to which a no more dignified term than that of room can be applied. Just consider for a moment the various types of “rooms” in which distinct reception of speech is of the greatest importance, e.g., committee rooms, court rooms, school rooms, board rooms, and so on, almost indefinitely.

This is a most important point, which may be expressed in a more concise way as follows:—

Every type of building has its own special acoustical problem on the correct solution of which depends, to a very large extent, its ultimate usefulness.

Unfortunately, at the present time in this country, the advantages that accrue from correct acoustical conditions are hardly even dreamt of by the vast majority of people.

Everyone, of course, is familiar with a number of buildings that are either famous or notorious for their acoustic properties ; but the benefits that result from the application of correct acoustic principles to the daily life of the office, factory and workshop are neither realised nor appreciated.

Here is a short extract from a leading article that appeared in an architectural paper dealing with investigations conducted by Professor Spooner, which should make the point quite clear. Professor Spooner remarks that the most serious aspect of the noise problem has received no attention.

" Few seem to realise the enormous loss due to impairment of working capacity and efficiency in city and industrial life ; more particularly as to men of affairs, principals and executives whose capacity for clear thinking, hard work, and energetic action is perceptibly weakened by the incessant if unconscious strain upon their nervous system caused by the din of typewriters and adding machines, and by the babel of noise penetrating into their offices from outside. The loss due to ill-health and premature death cannot be estimated, but the economic loss could conceivably be a great deal over £1,000,000 a week in America alone. Yet nothing worth mentioning appears to have been done in any country by the authorities responsible for the nation's health to protect the nervous health of the people in this respect."

In recent tests carried out by Professor Donald A. Laird at Hamilton, New York, he showed by the use of special apparatus, which measured the waste products in the breath as it was exhaled, that typists working under noisy conditions required 19 per cent. more energy to do a given amount of work than those working under quieter conditions.

Give it a moment's thought and it is quite obvious that this should be so, because any effort, whether conscious or subconscious, requires the expenditure of energy ; the effort necessary to eliminate the noise from the brain or the effort required to allow the brain to function normally without interference from extraneous noise, requires energy expenditure. The words "conscious" or "subconscious" have just been used as one so often hears it said, " Oh, that noise doesn't worry me ; I've got used to it." This " getting used to it " is really, however, another way of saying that the process of blotting out the sound has become a subconscious habit requiring the same energy expenditure in spite of the unconsciousness ; a machine requires the same motive power to drive it, whether we see the wheels going round or not.

Now, if noise can be eliminated altogether, or, at any rate, reduced (and it can be, as will be shown later), then very surely the efficiency of workers must be increased. For example, if typing errors can be decreased, what a lot of time, worry and temper would be saved. A typing error in the middle of an important letter coming up for signature late in the afternoon is an occurrence well calculated to ruffle the most placid of tempers and one with which most of us are all too familiar.

Now, as the title indicates, the practical view-point is the aim of this series. The author lays no claim to being a physicist. His work has been to take

the theories and data evolved by the physicists and to translate these into terms of timber and screws, so to speak. It will, of course, be necessary to introduce some theory in order to provide the foundation on which to build the practical structure, but, as far as is possible, it shall be kept to a minimum.

Here we cannot do better than start with the pronunciation of the word itself; should we say "a-coo-stics" or "a-cow-stics"? Greek scholars, no doubt, will adhere to the "cow," following the usual English pronunciation of the Greek verb, *ακουω*. As a personal preference the word seems more euphonious if tempered with a breath of Scotch antecedence by using the "coo" form. As a matter of fact, it is entirely a question of individual taste. Some dictionaries give one form, some the other. The new Oxford gives both.

And now, having disposed of that point satisfactorily, let us take a leap backwards to Ancient Greece and see what that civilisation knew of Acoustics. From the shape of their theatres, they had certainly discovered something regarding the distribution of sound in auditoria. No doubt the final form had been evolved after numerous attempts on rather a hit-or-miss principle; still, the ultimate results closely approximate to those which, following scientific principles, would obtain to-day. They grouped their audience in semi-circles and packed the seats as close as possible, by raising them tier on tier. They had a hard surface behind their stages to act as a sound reflector and, if some of their writings are to be believed, attempts to reinforce the voice were made by standing the actors on small wooden boxes and by placing large earthenware jars in niches in the side walls, thus showing that they had some ideas about the phenomenon we know as resonance.

Also, they were quick to turn any natural formations to their own use; the most notable example of which, I suppose, is that of the Tyrant Dionysius listening to the conversations of his slaves in the valley by means of the now famous ear at Syracuse in Sicily.

From Greece to Rome is not a far cry, and we find in the works of Vitruvius (*De Architectura*, Liber V) a considerable insight into the requirements of good theatre acoustics. In one passage he refers to certain terms used by the Greeks, and there is little doubt that his investigations had followed on the lines which they had started. On the other hand, there is Virgil's assertion that an echo was harmful to bees, whilst the story of the Nymph Echo and the Youth Narcissus provides a legendary, if somewhat dubious, explanation of the phenomenon.

After Roman times, the addition of roofs to auditoria complicated the question considerably, and all investigations seem to have been dropped for centuries. In fact, it is not until the beginning of the last century that technical writings again began to make their appearance, with the possible exception of a passage, though this can hardly be called technical, in Gilbert White's "*Natural History of Selbourne*." In this work, there is a letter written

to the Hon. Daines Barrington, dated 12th February, 1778, in which he describes an echo and states how it would repeat ten syllables provided they were short, quick ones (dactyls). He further shows, from measurements, that the ratio of the distance between the reflecting and hearing points to the number of syllables is 75. The figure should be noted as its significance will appear later.

And now we come to the real dawn of our present exact science. In 1895 Professor Wallace Clement Sabine was instructed by the University of Harvard to undertake the investigation. This he did with such outstanding success that during the next 20 years he was able to lift the science out of the realms of conjecture and uncertainty and place it on a sound and sure basis.

Contemporary with Sabine are the works of Lord Rayleigh, whose "Theory of Sound" (1896) can be termed a classic on the subject; the work of Professor Jaeger (1911) is also quite well known, while, to bring the resumé right up to date, we must include the recently published work by Drs. Davis and Kaye, of the National Physical Laboratory, which so ably co-ordinates the results of numerous writers with their own investigations.

From the foregoing it will be seen that there is plenty of literature for the student to assimilate, if he wishes to delve deeply into the subject.

Good acoustics! The phrase has already crept into the text once or twice, but just what does it mean? It is a little difficult to allot absolutely precise conditions, as so much depends on the taste and requirements of the individual. There is the story of the new Councillor, very full of his own merits as a speaker, enquiring of an old member about the acoustics of the Council Chamber. "Fine," replies the other, "if you sit well back you can sleep comfortably as you can't possibly hear a word."

Professor W. C. Sabine has given us some general principles and we cannot do better than take his actual words and then analyse them in the light of practical experience. He says:—

"In order that hearing may be good in any auditorium, it is necessary that the sound should be sufficiently loud, that the simultaneous components of a complex sound should maintain their proper relative intensities and that the successive sounds in rapidly moving articulation either of speech or of music, should be clear and distinct, free from each other and extraneous noises. These three are the necessary, as they are the entirely sufficient, conditions for good hearing. Scientifically, the problem involves three factors; reverberation, interference and resonance. As an engineering problem, it involves the shape of the auditorium, its dimensions and the materials of which it is composed."

There, in a few words, are the requirements, and it all sounds fairly simple. Personal taste, however, plays a big part in their interpretation. In this direction, Professor Watson, of the University of Illinois, has helped considerably by taking a large number of buildings of all sizes. These buildings had, by common consent, been pronounced good for their special functions,

either speech alone, or music alone, or for a combination of the two. He has classified them and produced in graph form a curve connecting their various characteristics.

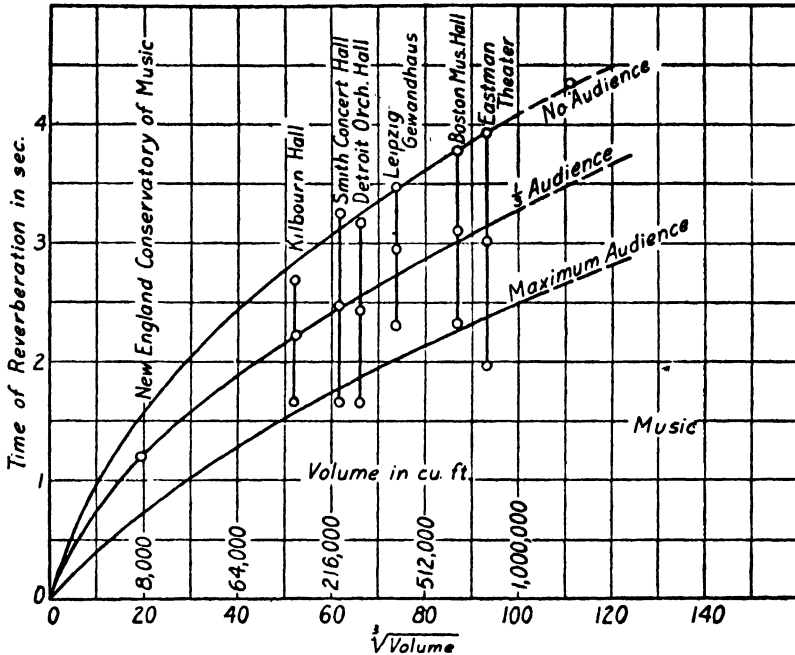


FIG. 1. The above Graph, published by the courtesy of Professor F. R. Watson, University of Illinois, shows the relation between the period of reverberation and the volume for a number of buildings adjudged good for music.

Now to analyse Sabine's conditions. His first one, namely "that the sound must be sufficiently loud," may, at first sight, be thought rather self-evident. It would obviously be no use to expect to hear the unaided voice of a speaker all over the Stadium at Wembley, for instance. But the condition is not quite so simple or straightforward as at first sight it might appear. Before the condition of adequate loudness can be fully understood some knowledge regarding the production and dissipation of sound is necessary.

Sound is a form of energy and as such must continue as sound energy until transformed into some other kind; it cannot be destroyed, as energy is indestructible. Usually the transformation is effected by friction producing heat energy, the friction being set up between the sound waves and the medium through which they pass or with which they come in contact. Friction causes heat, and so, as the sound dies away, heat is generated. This does not mean that the problem of cheap heat has been solved. It's no use inviting a loquacious friend on a cold winter evening and expecting to be

able to do without a fire. Some serious-minded person once went to the trouble of working out how much heat was actually generated by a person talking, and he came to the conclusion that if half-a-million people talked for two hours, he'd be able to boil sufficient water to make a cup of tea!

Now, suppose we have a source of sound like an organ pipe, emitting a constant note and then suppose we fit a toy balloon over it. The wind from the pipe will gradually blow it up and we shall see it as an ever-increasing sphere, growing, as it were, from the pipe, till it bursts. That's a reasonable visualisation of the spread of a sound wave—spherically from its source. In thinking of waves, their composition must not be lost sight of, for, in a wave, there is not only the crest like that of the sea wave it is so refreshing to dive through on a hot summer day, but, also the trough that follows it. Perhaps, in trying to visualise a sound wave, it will be easier to consider it as being composed of two waves, the first a wave of compression, the second a wave of rarefaction.

As a parallel, imagine a punchball, suspended between floor and ceiling, receiving a sharp, horizontal blow. As the ball moves forward it will compress the air in front of it and, at the same time, create a partial vacuum behind—condensation, rarefaction.

Wave length is, of course, the distance from crest to crest or trough to trough.

Sounds are identified like wireless stations, either by their wave length or by what is termed their frequency, which is the number of vibrations they make per second. As the speed of sound is constant, the more vibrations there are per second, the shorter must be the wave length. Thus

$$\text{wave length} = \frac{\text{speed}}{\text{frequency}}$$

Perhaps a zoological illustration will make this question of speed and frequency clearer:—

Once upon a time, Mr. Python was going for a walk, or rather a wriggle, when he chanced to meet Mr. Viper. After passing the time of day, they decided to continue their walk together. Mr. Python set off by wriggling his body in large, slow undulations, while Mr. Viper had to wriggle his tiny body very quickly indeed in order to keep up with him, and so produced a large number of small, quick undulations. They were thus both travelling at the same speed, but Mr. Viper had many more wriggles to the second than Mr. Python.

Another point needs consideration, and that is what happens when a sound wave strikes some surface, say a wall, for example. Three actions take place, part of its energy is transmitted, part is transformed by friction, whilst the remainder is reflected; and it is with the two latter actions we are mainly concerned. If the surface is hard and dense, like plaster or glass, very little friction will be set up, and, consequently, the bulk of the energy will be

reflected and the sound will be little reduced in intensity in consequence. In point of fact, most materials in common use as "finishes" to walls and ceilings, are better reflectors of sound than a good mirror is of light, and, having mentioned light, there is another point of comparison that will be found of use. For practical purposes, it can be said that sound is reflected in the same ways as light, i.e., the angle of incidence equals the angle of reflection, defraction being ignored.

In place of the hard surfaces just mentioned, suppose there are soft, yielding ones, like curtains or feather beds. It is quite obvious that considerable friction must be set up as the wave penetrates and, more or less, loses itself in the interstices of the material; consequently, a great deal of its energy is lost and very little reflected.

Bearing the foregoing in mind, it will be seen that the question of adequate loudness is not quite as simple as it might at first appear. In the open air the only sound normally reaching an "observer" is that which travels directly between the source and himself, and so, the greater the distance the less is the intensity of the sound. In a confined space, such as a building, an observer not only receives the direct sound, but is also assailed by a conglomeration of reflections from all the bounding surfaces, thus increasing or reinforcing the direct sound. Thus the original intensity can be described as being built up by reflection until a point of saturation is reached where energy is being produced at the same rate as it is being dissipated, and so the intensity becomes constant. When, therefore, Sabine says the sound must be sufficiently loud, he is referring to the constant intensity built up by reflection.

Reflection, therefore, may be regarded as an asset. In this world, however, most assets have a corresponding debit, and reflection is no exception and the debit is there sure enough.

Remembering the crest and trough of the wave, consider what happens should the paths of the two parts of the same wave, having travelled an equal distance by being reflected from different surfaces, come together again; the crest of one will arrive at the same moment as the crest of the other and there may thus be mutual reinforcement. On the other hand, it may well be that the crest of one will correspond with the trough of the other, so that instead of reinforcement, a neutralising effect will be produced, which, in turn, would produce a zone of comparative quiet.

From this it might appear that to get reinforcement by reflection is almost an impossibility, but it must be remembered that there is an almost infinite number of reflections crossing and recrossing each other, so that if it can be arranged that reflections are evenly distributed over the area occupied by the observers or the audience, the neutralisation effect is not noticeable. When, however, the shape of the building is such as to cause concentration of reflection in certain areas, as sometimes happens in the case of barrel

ceilings or domes, then trouble may be expected. This question of reflected sound is usually referred to as the "interference system" of the building. The securing of adequate loudness, therefore, involves the production of a uniform interference system.

Sabine's next two conditions will be considered together, as they are very closely related. He says that the simultaneous components of a complex sound shall maintain their proper relative intensity and that the successive sounds in rapidly moving articulation, either in speech or music, shall be clear and distinct, free from each other and from extraneous noise.

These two conditions depend chiefly on the phenomenon of reverberation, which is one of the most important in the whole science. It is safe to say that in the proper control of reverberation lies the solution of 90 per cent. of acoustical problems.

It has already been shown that sound energy is dissipated in one way or another, and it must have been evident that this dissipation takes place over a period of time. Suppose an organ pipe is allowed to go on sounding until the intensity is constant and then the air supply is suddenly cut off. Some period of time must elapse before the sound finally dies away. It is this period of decay that is termed the period of reverberation and it is measured in seconds. The text book definition of reverberation is:—

"The time taken by a constant sound of average intensity to die away past the threshold of audibility after the source creating it has been stopped."

In this definition, a constant sound is taken to mean a sound sustained for sufficient time to allow of its completely filling the whole volume, whilst average intensity is 1,000,000 times the threshold of audibility.

Reverberation is, therefore, dependent on the rate at which the bounding surfaces transform the sound energy, which property of transformation is called absorption, whilst the degree to which the property is possessed is the co-efficient of absorption.

Reverberation is dependent on absorption; also, as a constant intensity must first be reached, reverberation must be dependent on the volume as well, since the intensity cannot be constant until the whole volume is filled. Quite obviously, the larger the volume the more energy will be required to fill it.

Professor Sabine has shown that if the time of reverberation = t , then

$$t = \frac{KV}{A}$$

where K is a constant (0.05) and A is the total absorbing power of the building. This is now the standard reverberation formula.

The co-efficients of absorption of practically all building materials have been determined and some of them are set out in the following table which has been compiled from the results obtained by a number of investigators:—

TABLE I.
COEFFICIENTS OF ABSORPTION.

Materials, etc.								Units per Sq. Ft.
Open Window	..	..	..	..	..	..	..	1.00
Audience	..	..	..	..	..	per person	..	4.70
Cabot's Quilt, 2 layers 3-ply	..	..	..	..	..	..	..	0.60
Hairfelt, 1 in. thick, with unpainted membrane	..	..	..	..	..	..	..	0.55
Flax, 1 in. thick, with unpainted membrane	..	..	..	..	..	..	..	0.55
Curtains, in heavy folds	..	..	..	..	..	..	0.50 to	1.0
Akoustolith (artificial stone)	..	..	..	..	..	..	..	0.40
Acoustic plaster	..	..	..	..	..	..	..	0.30
Brick wall, 18 in. thick	..	..	..	..	..	..	..	0.032
Brick wall, painted	..	..	..	..	..	..	..	0.017
Brick, set in Portland cement	..	..	..	..	..	..	..	0.025
Carpets, unlined	..	..	..	..	..	..	..	0.15
Carpets, lined	..	..	..	..	..	..	..	0.20
Carpets, heavy with lining	..	..	..	..	..	..	..	0.25
Carpet rugs	..	..	..	..	..	..	..	0.20
Coco matting, lined	..	..	..	..	..	..	..	0.17
Concrete	..	..	..	..	..	..	..	0.015
Cork tile	..	..	..	..	..	..	..	0.03
Cretonne cloth	..	..	..	..	..	..	..	0.15
Curtains, chenille	..	..	..	..	..	..	..	0.23
Glass, single thickness	..	..	..	..	..	..	..	0.027
Linoleum	..	..	..	..	..	..	..	0.03
Marble	..	..	..	..	..	..	..	0.01
Plaster on wood lath	..	..	..	..	..	..	..	0.034
Stage opening, depending on stage furnishing	..	..	..	..	..	..	0.25 to	0.40
Varnished wood	..	..	..	..	..	..	..	0.03
Wood sheathing	..	..	..	..	..	..	..	0.061

One method of doing this is to take a test room finished entirely with hard reflecting surfaces and measure its reverberation. A selected area of wall surface, say, 100 sq. ft., is then removed so that all sound which would normally strike that area passes through to the open air and is lost. In other words, a space of 100 sq. ft. of totally absorbing area has been secured. The reverberation is again measured. This totally absorbent area is then filled up and finished as before, and now the materials for test are introduced using sufficient to produce the same reverberation as with the wall open. By this means the ratio of absorption can be readily obtained and is then expressed in a percentage of 1 sq. ft. of the open wall. This unit is called an open window unit. Thus plaster on brick is only $2\frac{1}{2}$ per cent. as absorptive as an open window, or, expressed the other way round, its coefficient of absorption is .025 open window units.

So far so good ; but another complication introduces itself here, and that is that the coefficient varies with the pitch of the sound. The figures given in the table have been computed for the octave above middle C or, in slightly more technical form, C_4 512 : the figure 512 being the number of vibrations per second or, in other words, the frequency. From this the wave length of the note can be calculated—approximately $\frac{1200}{512}$ ft. (taking the speed of sound in round figures as 1,200 ft. per second), which equals 2.34 ft.

When the co-efficient of a material is small, as in the case of glass and plaster, its varying absorbing value makes but little difference. When, however, materials possessing high values like felt or Cabot's quilt are being considered, very curious and unexpected results may be obtained. The absorption graphs of most materials over the compass of seven octaves is more or less in the form of an inverted parabola with the maximum lying somewhere between C_3 and C_4 . As something more than 50 per cent. of speech sounds lie within this range, the variation does not make so much difference as might at first be imagined.

In music, however, it is of considerable importance ; for, suppose the reverberation of a bass note is 50 per cent. longer than that of one in the middle register, it is easily seen that the balance of a chord may be easily upset ; or, to take the case a step further, an organ might sound a discord whilst its reverberation might appear to be in harmony because of the rapid elimination of the discordant tone. Further, as practically all notes are complex, consisting usually of several over-tones besides the fundamental, it may happen, due to uneven absorption and reinforcement, that although a constant note may be continuously emitted, an observer on moving about the building, may find that it sounds an octave higher in one place than in another. When, therefore, Sabine lays down that the simultaneous components of a complex sound shall maintain this proper relative intensity, he is setting no easy task.

Composers, naturally, have been very alive to these effects, and enthusiastic musicians will tell you that to hear a piece rendered as the composer intended, you must hear it played in the building for which it was composed. A notable example occurs in some of Fairfax's works, written specially for St. Alban's Cathedral, where the peculiar acoustic conditions are supposed to bring out a fourth part that does not actually appear in the score.

Just as reverberation plays such an important part in the relative intensities of the components of a complex sound, so it is of equal importance in keeping clear, distinct, rapidly-moving, successive sounds. Taking a hypothetical case, suppose a church has a reverberation of four seconds, by no means an abnormal figure, it will be readily understood that all sounds created will take four seconds to die away ; thus, if four notes are struck in rapid succession

their individual reverberation will blend and will still be audible three seconds later ; whilst, should a quick succession of notes be struck in the same period, worst confusion will result.

Next, consider what happens in the case of speech, taking the unit of speech as the syllable and the normal rate as four syllables per second. With a reverberation of four seconds, we see that when the speaker is uttering his sixteenth syllable, there is a conglomeration of the fifteen preceding syllable-sounds through and above which the congregation will have to distinguish the orderly procession of all the syllables. It simply cannot be done !

Here the question might well be asked : Is it possible to hear at all ? It has, moreover, already been said that reflections, which mean reverberation, are necessary to secure adequate loudness. This seems paradoxical and well it might be, were it not for two facts.

The first is a habit formed by long necessity ; for our ears have become used to a certain amount of overlapping of sounds, so that where this is absent, as is usually the case in the open air, we feel a sense of irritation at the dullness or colourlessness of the sound. The second is that, although our hearing organism would be described as very sensitive, yet it has its limitations, and we cannot distinguish as separate sounds those that arrive at intervals of less than $1/15$ of a second ; anything quicker than that appears as a continuous sound.

In $1/15$ second sound will travel approximately 75 to 80 ft. (note this figure in relation to that given by White in 1778), which means that when we are considering reinforcement by reflection, we can have a difference in the path of two rays of sound of up to 80 ft., and yet they will appear as one simultaneous sound.

Referring back to Dr. Watson's graph, it will be seen that the optimum time of reverberation varies from one to two seconds, depending on the size of the building and the uses to which it is to be put. A longer period can be used for music, with advantage, than for speech, whilst the larger the building the longer the time taken for the intensity to become constant. When, however, speech is taking place in a large building with a longish reverberation period, it is necessary for the speaker to enunciate more deliberately in order to reduce, to some extent, the normal rate of syllabic utterance.

There is one special case of reverberation familiar to everyone which, so far, has not been touched, namely echo. Echo is caused by sound striking some hard, dense surface and being reflected by it back to the observer. When echoes are met with out-of-doors, the observer usually creates the sound and then waits for it to be returned to him again. In some cases it may be returned several times at intervals, as different parts of the same wave strike different reflecting surfaces. No doubt some of you have listened to the marvellous effects produced by the Alpine horns in Switzerland.

When an echo is produced in a building it is usual for the sound to be produced from a stage or rostrum and for the echo point or points to be some distance away. In this case the observer hears the direct sound from the stage and then the echo, as if the source had been moved to some other position.

We have already seen that the direct and reflected paths can have a difference in length of from 75 to 80 ft. and still appear as one sound. But if this distance is increased the direct and indirect sounds will separate, and the more the distance is increased the more distinct and pronounced will the separation become, in other words, the echo becomes clearer and more noticeable.

Echo is also more pronounced when the surface causing the reflection is so shaped as to concentrate the returning sound direct on to the spot where the observer is placed; often at a few feet away from this position it may not be noticeable at all.

The last phenomenon that must be considered is Resonance, and here, whilst both the cause and effect are appreciated, considerably more research is required. Resonance is a term that is very loosely used; in fact, it is quite often used to describe almost any of the acoustical phenomena. It has, however, a very definite meaning and should be applied only to one particular set of circumstances. In scientific literature, resonance is used to describe the phenomenon, wherever it may occur, of the growth of a vibratory motion of an elastic body under periodic forces timed to its natural rates of vibration.

For instance, troops passing over a suspension bridge are ordered to "break step" lest the rhythmic force of marching "in step" should, through resonance, cause undue strain. Sabine gives the following illustration and makes the action of resonance clear:—

"If the palm of the hand be placed on the centre of the surface of water in a large basin or tank and quickly depressed and raised once it will cause a wave to spread, which, reflected at the edge of the water, will return, in part at least, to the hand. If, just as the wave reaches the hand, the hand repeats its motion with the same force, it will reinforce the travelling over the water. Thus reinforced, the wave goes out stronger than before and returns again. By continued repetition of the motion of the hand so timed as to reinforce the wave as it returns, the wave gets to be very strong. Instead of restraining the hand each time until the wave travelling to and fro returns to it, one may so time the motion of the hand as to have several equal waves following each other over the water, and the hand each time reinforcing the wave that is passing. This, obviously, can be done by dividing the interval of time between the successive motions of the hand by any whole number whatever, and moving the hand with the frequency thus defined. The result will be a strong reinforcement of the waves. If, however, the motions of the hand be not so timed, it is obvious that the reinforcement will not be perfect, and, in fact, it is possible so to time it as to exactly oppose the returning waves. The application of this reasoning to the phenomenon of sound, where the air takes the place of the water and the sounding body that of the hand, needs little additional explanation. Some notes of a complex sound are reinforced, some are

not and thus the quality is altered. This phenomenon enters in two forms in the architectural problem : there may be either resonance of the air in the room, or resonance of the walls."

Thus, resonance alters the total amount of sound in a room and, in fact, always increases it or, rather, increases the sound of those notes that cause it, and those notes only, so exerting an unbalancing effect. Also every building seems to have at least one note which will sound louder than any other, we might say its own peculiar note to which it responds. This is caused by the resonance of the air and is of particular importance in the tuning of a new organ after installation.

Of all resonant materials used in building construction, wood is the most important, as it will respond to a large number of notes. Platforms, pulpits, etc., are nearly always wood because it has been found that the material assists a speaker considerably. It seems to impart a carrying power to the voice that is absolutely lacking when the speaker stands on stone or other similar material ; and the same applies to instruments that rest on the floor, such as a 'cello and the like.

We know, from experience, that wood responds in this way, but the information lacking is as to the effect that the thickness, the position of the supports and even the various kinds of wood have in regard to the resonating pitch. Definite data in this direction would be of very great value, particularly in connection with the provision of adequate loudness.

To sum up, every building has its own special acoustical problem, the scientific solution of which involves the factors, reverberation, absorption, resonance and interference, whilst the practical solution involves the shape of the building, its dimensions and the materials used to build it.

NOTES ON BOOKS.

THE OLD COTTAGES AND FARM-HOUSES OF NORFOLK. By C. J. W. MESSENT.
Norwich : H. W. Hunt. 10s.

Foreigners coming to England are lost in admiration of our cottages. The county of Norfolk, for instance, is rich in old cottages and farm-houses. These do not, as Mr. Messent says, " stand out so majestically as the fine old churches, nor do they take such an important place as the Manor Houses . . . but they have an individuality of their own . . . and seem to be a natural part of the landscape," this last charm being due to the use of local materials. The exquisite blue of Cotswold cottages is also due to the use of local stone ; but this is unfortunately rather porous, and is the cause of considerable inconvenience.

The beautiful little houses described by Mr. Messent stand in a very satisfactory relationship to the needs of human beings. A certain feeling of culture attaches to their forms, and emanates from their proportions. To live in them is a good thing in itself. Many modern villas may keep out the rain as efficiently and be full of gadgets into the bargain, but if there is any other satisfaction bound up with living in them it speaks ill for the tenants that experience it.

Without being quite as expert an architectural draughtsman as, say, Raffles Davison, Mr. Messent—who writes admirably—makes very attractive drawings of his subjects. The unpretentiousness of his stylised trees, hedges and flower-beds goes well with the simple lines by which he suggests the surface texture of his cottages.

Brick and flint are the principal building materials of Norfolk, but clay-lump, carstone, hard chalk lump (known as clunch), wattle and daub, half-timber work and weatherboarding are also found. The old Hall Farm at Bedingham and the Walnut House Farm are charming examples of brick construction. Both these also show Dutch influence in their pleasant curved gables. To the Low Countries Norfolk is indebted not only for such gables, but also for the vogue of brick and the use of pantiles on the roof.

The comparative scarcity of timber-framed buildings in Norfolk is explained by the fact that in the middle ages the county was hardly better wooded than it is to-day; yet, as Mr. Messent's illustrations show, such cottages as were built in this way were none the less well conceived. The Old Hall Farm House at Tacolneston is quite romantically beautiful. Its remarkable front porch "might be described as a three-storey wing projecting centrally from the front elevation." A certain elaborateness of detail—how fatal it would probably be to-day!—is most agreeable.

At the end of his book Mr. Messent has a chapter on barns and dovecotes. The barn at Carleton St. Peter is delightful. And how pitiful it is to read that the "Dovecotes or Pigeon-Houses are fast falling into decay and disappearing." What are people putting in their place? Not exquisite little homes for their baby Austins. All the dovecotes shown in the illustrations are fine. That at Dunston has a threefold roof of Germanic character. The one at Westwick spans the road in the form of an arch. The dovecote at Barningham suggests a kind of primitive but inspired ingenuity.

Mr. Messent's book, it may be said, is well printed, and is attractive to eye and hand.

THE ENGLISH WATER COLOUR PAINTERS. By C. E. Hughes. London: Benn Bros., Ltd. 6d.

La peinture d'huile, says a French epigram, *est plus difficile que la peinture d'eau; mais c'est d'autant plus beau*. We need not concern ourselves with the second affirmation, but as to the first, water colour painting is not so easy as to have allowed of the production of many masterpieces. Since the late Georgian period all well brought up young ladies have been taught to paint in water colours. How many of them have afterwards been inspired to create anything worth preserving? To this day they are known to keep records of travel in water colour instead of photographs, and, though this is commendable, the interest of their pictures is topographical rather than æsthetic.

When Wenceslas Hollar introduced water colours into England in the second quarter of the seventeenth century it was precisely to topography that he devoted himself, and for quite a hundred years nobody thought of attempting much else in this medium. The first moves in a new direction were not very exciting; they were pen work "washed with transparent tints in a limited range of colouring," and were known as "stained drawings." Then at last, when the vogue for the picturesque swept over England (see "Headlong Hall") the water colour artists extended their scope from tidy representations of gentlemen's country seats to views of romantic ruins, abbeys, castles and so forth, both at home and abroad.

Mr. Hughes manages to pack a great deal of information into his seventy-eight pages. He is excellent on technique and treatment. J. R. Cozens was the man who first really got away from the bondage in which his art had been kept by its architectural connection. Though he still belonged to the period of "stained drawings" he was not as meticulous about detail as his predecessors. He showed the way to others, and by the end of the eighteenth century and the beginning of the nineteenth the art had risen to new heights. Water colour sketches by Gainsborough and the early work of Turner are not inferior to *peinture à l'huile*.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

- MONDAY, OCTOBER 15.** East India Association, at Caxton Hall, Westminster, S.W. 4.30 p.m. Rev. Father Ivan der Schueren, "Aboriginal Uplift in Chota Nagpur."
- Heating and Ventilating Engineers, Institution of, at the Borough Polytechnic, S.E. 7.30 p.m. Debate "Steam versus Hot Water Heating."
- Metals, Institute of, at the Applied Science Department, University of Sheffield. 7.30 p.m. Mr. Cosmo Johns, "Influence of Pressure on Rocks and Metals." (Sorby Lecture).
- University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Mr. C. A. Macartney, "Austria."
- At University College, Gower Street, W.C. 5 p.m. Prof. E. B. Verney, "Urinary Secretion." (Lecture I).
- 5.30 p.m. M. Marcel Bouteron, "Balzac." (Lecture I).
- TUESDAY, OCTOBER 16.** Arts, Royal Academy of, Burlington House, W. 4.30 p.m. Prof. Arthur Thomson, "Anatomy." (Lecture V).
- Heating and Ventilating Engineers, Institution of, at Milton Hall, Manchester. 7 p.m. Mr. A. Hindley, "Pipe Sizing for Hot Water Supply Installations."
- University of London, at Bedford College for Women, Regent's Park, N.W. 11 a.m. Miss Johnson, "Pioneers in Romance Philology."
- 5 p.m. Prof. Mackie, "Queen Mary and King James." (Lecture I).
- At King's College, Strand, W.C. 5.30 p.m. Engineer-Captain Edgar C. Smith, "One Hundred Years of Naval Engineering." (Lecture I).
- At University College, Gower Street, W.C. 5.30 p.m. M. Marcel Bouteron, "Balzac." (Lecture II).
- WEDNESDAY, OCTOBER 17.** Constructive Birth Control and Racial Progress, Society for, at Essex Hall, Essex Street, Strand, W.C. 8 p.m. Dr. M. Beddon Bayly, "Voronooff and his Rejuvenation Experiments."
- Central Asian Society, at Burlington House, W. 5.30 p.m. Mr. L. F. Rushbrook Williams, "The Indian States and the New Constitution."
- Glass-Painters, British Society of, at 6, Queen Square, W.C. 5.30 p.m. The Very Rev. W. Foxley Norris, "The Stained Glass of York Minster."
- Microscopical Society, 20, Hanover Square, W. 7.30 p.m. Messrs. J. E. Barnard and F. V. Welch, "An Electrically Heated Warm Stage with Compressor for use with High Power Objectives." Prof. Dr. E. Ghosh, "Two New Ciliates from Sewer Water."
- Oil and Colour Chemists' Association, at the Royal Society of Arts, Adelphi, W.C. 7 p.m. Discussion on Colour Standardisation and Testing in the Paint and Colour Industry.
- Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Dr. E. Graham Little, "The Health of the Medical Practitioner."
- University of London, at King's College, Strand, W.C. 5.30 p.m. Sir Oliver Lodge, "The Indebtedness of Industry to Pure Science." (Lecture I—"Introduction.")
- 5.30 p.m. Sir Bernard Pares, "Contemporary Russia." (Lecture II).
- At the London School of Economics, Houghton Street, W.C. 6 p.m. Mr. A. T. Rouse, "Some Uses of Burroughs' Machines."
- At University College, Gower Street, W.C. 5.30 p.m. Mr. J. H. Helweg, "The Romantic Movement in Denmark."
- At the University Union Society's Rooms, Malet Street, W.C. 5.30 p.m. Dr. Julian Krayznowski, "Renaissance Poland." (Lecture III).
- THURSDAY, OCTOBER 18.** Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m. Mr. H. Sutton, "Light Alloys and their Use in Aircraft—with special reference to Corrosion Problems."
- Antiquaries, Society of, Burlington House, W. 8.30 p.m. Chemical Society, Burlington House, W. 8 p.m. 1. Messrs. T. M. Lowry, H. Moureu, and C. A. H. MacConkey, "Studies of Dynamic Isomerism." Part XXVIII. "Absorption Spectra of the Ketonic and Enolic Forms of an α -Diketone." 2. Messrs. W. A. Kirkby and R. V. Wheeler, "Explosions in Closed Cylinders." Part I. "Methane-air Explosions in a Long Cylinder." Part II. "The Effect of Length of the Cylinder." 3. Messrs. O. C. de C. Ellis and R. V. Wheeler, "Explosions in Closed Cylinders." Part III. "The Manner of Movement of Flame." 4. Messrs. B. Flürscheim and E. L. Holmes, "Pentanitroaniline."
- Metals, Institute of, at the Engineer's Club, Birmingham. 7 p.m.
- University of London, at Bedford College for Women, Regent's Park, N.W. 4.15 p.m. Prof. Eccles, "Pierre Corneille." (Lecture III). (In French).
- At King's College, Strand, W.C. 5.15 p.m. Rev. Norman Sykes, "Bossuet."
- 5.30 p.m. Mr. Geoffrey Shaw, "Carols."
- At the Memorial Hall, Farringdon Street, E.C. 6 p.m. Rev. Dr. Selbie, "The Soul and its Destiny."
- At University College, Gower Street, W.C. 4 p.m. Dr. D. H. Scott, "Aspects of Fossil Botany." (Lecture I).
- 5.30 p.m. Capt. C. J. C. Little, "Naval Bases and Sea Power."
- 5.30 p.m. Miss E. Jeffries Davis, "Historical Factors of the Problem of London Traffic." (Lecture II).
- At the University Union Society's Rooms, Malet Street, W.C. 5.30 p.m. Prof. Dr. R. W. Seton-Watson, "The Old Kingdom: A Political Survey (1856-1914)."
- FRIDAY, OCTOBER 19.** Arts, Royal Academy of, Burlington House, W. 4.30 p.m. Prof. Arthur Thomson, "Anatomy." (Lecture VI).
- Electrical Development Association, at the Royal Society of Arts, Adelphi, W.C. 7.30 p.m.
- Mechanical Engineers, Institution of, Storey's Gate, S.W. 6 p.m. Mr. Richard W. Allen, Presidential Address.
- University of London, at King's College, Strand, W.C. 5.30 p.m. M. Denis Sauret, "Marcel Proust as a Novelist." (Lecture I). (In French).
- At University College, Gower Street, W.C. 5 p.m. Prof. Dr. Tancred Borenius, "Early Christian Art." 5 p.m. Prof. Dr. J. C. Drummond, "Recent Work on Vitamins." (Lecture II).
- 5.30 p.m. Sir Josiah Stamp, "The Working of the Dawes Plan."
- At the University Union Society's Rooms, Malet Street, W.C. 5.30 p.m. Prof. Dr. R. W. Seton-Watson, "The Collapse of Austria-Hungary." (Lecture II).
- SATURDAY, OCTOBER 20.** L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Miss M. A. Murray, "Sculpture in Ancient Egypt."

JOURNAL OF THE ROYAL SOCIETY OF ARTS

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FRIDAY OCTOBER 19th, 1928.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.(2.)

NOTICES.

THOMAS GRAY MEMORIAL TRUST.

PRIZES FOR THE IMPROVEMENT AND ENCOURAGEMENT OF NAVIGATION.

Under the above trust the Council offer the following Prizes :—

(i) A Prize of £100 to any person who may bring to their notice a valuable improvement in the Science or Practice of Navigation proposed or invented by himself in the years 1927 and 1928.

In the event of more than one such improvement being approved, the Council reserve the right of dividing the amount into two or more prizes at their discretion.

Competitors must forward their proofs of claim on or before December 31st, 1928, to the Secretary, Royal Society of Arts, John Street, Adelphi, W.C.2.

(ii) A Prize of £50 for an essay on the following subject :—

“ The Practice of Navigation in the Mercantile Marine.”

The essay must be based on the actual methods used by the writer during his career, with special reference to the instruments used as aids to navigation, and the effect of stowage of cargo on the steering, speed and safety of the vessel.

Competitors must send in their essays not later than December 31st, 1928, to the Secretary, Royal Society of Arts.

The essays must be typed or clearly written. They must be sent in under a motto, accompanied by a sealed envelope enclosing the author's name.

The Judges will be appointed by the Council.

The Council reserve the right of withholding the Prize or of awarding a smaller Prize or Prizes, if in the opinion of the Judges no suitable essay is submitted.

The Council also reserve an option on the copyright of the successful essay.

COUNCIL.

A meeting of the Council was held on Monday, October 8th. Present :— Sir George Sutton, Bt., in the Chair ; Mr. Llewelyn B. Atkinson, M.I.E.E. ; Sir Charles H. Armstrong ; Rt. Hon. George N. Barnes, C.H. ; Captain Sir Arthur Clarke, K.B.E. ; Sir William Henry Davison, K.B.E., D.L., M.P. ; Mr. Peter MacIntyre Evans, M.A., LL.D. ; Rear-Admiral James de Courcy Hamilton, M.V.O. ; Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S. ; Sir Herbert Jackson, K.B.E., F.R.S. ; Major Sir Humphrey Leggett, R.E., D.S.O. ; Sir Phillip Magnus, Bt. ; Sir Henry A. Miers, F.R.S. ; Sir Richard Redmayne, K.C.B. ; Mr. Alan A. Campbell Swinton, F.R.S. ; Professor John Millar Thomson, LL.D., F.R.S., and Mr. W. J. U. Woolcock, C.B.E., with Mr. G. K. Menzies, M.A. (Secretary), and Mr. W. Perry, B.A. (Assistant Secretary).

The following candidates were duly elected Fellows of the Society :—

Alam, M. H., Cawnpore, India.

Bakhshi, Pandit Janaki Nath, B.A., Srinagar, Kashmir, India.

Barker, Arthur Henry, M.Inst.C.E., London.

Bland, Joseph Powell, Kidderminster.

Bossom, Alfred C., F.R.I.B.A., London.

Browning, E. L., London.

Carmichael, William Robert, Vancouver, B.C., Canada.

Carpenter, Alfred, London.

Crompton, John, O.B.E., M.Sc., Lytham, Lancs.

Devenish-Meares, Clive, Rabaul, New Guinea.

Edwards, Herbert, Bury, Lancs.

England, Arthur John, Southall, Middlesex.

Fisk, Eugene L., M.D., New York City, U.S.A.

Fripp, Paul, Cheltenham.

Garton, Richard Henry, London.

Gillespie, N. A., London.

Gillinson, Louis A., Leeds.

Gladwell, Leonard V., Whaley Bridge, Cheshire.

Gloag, John, London.

Guieu, Paul, London.

Hansen, Carl Lauritz, Cholsey, Berks.

Hardwick, Robert Alan, Fort William.

Heath, John Edgar, Bickley, Kent.

Horstmann, Albert, Bath.

Kanojia, Makesh Narain, Delhi, India.

Leighton, Robert, London.

Lyon, Jeremiah Malcolm, Orford, Suffolk.

MacDonald, Ranald, Dikom, Assam, India.

Mohanlal, Manilal, Karachi, India.

Moore, William Alfred, London.

Mosthaf, Edwin Frederick, Montreal, Canada.

Naugle, John Jay, New York City, U.S.A.

Peck, James E., M.A., San Diego Co., California, U.S.A.

Pope, Arnold F., Thornton Heath, Surrey.

Quinton, Reginald William Anthony, London.

Stone, George, Watford, Herts.

Schee, John Hudson, Kudat, British North Borneo.

Seccombe, Thomas, Cardington, Bedford.

Unwalla, J. N., Bombay, India.

van Stratey, Leon, London.

Wainwright, Shirley B., London.

Wolstenholme, Harry V., F.R.I.B.A., Blackburn.

Wreford, G. M. Felton, London.

The arrangements for the forthcoming session were considered.

Mr. E. Spencer, whose design for the Swiney Cup was awarded a prize of £25 at the recent Competition of Industrial Designs, was commissioned to execute the cup.

Dr. R. Lessing was appointed to represent the Society at the forthcoming International Conference on Bituminous Coal, to be held in Pittsburgh, U.S.A.

The thanks of the Council were accorded to the Court of the Clothworkers' Company for again contributing £40 towards the provision of medals in connexion with the Society's Examinations, in 1929.

A quantity of financial and formal business was transacted.

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

ACOUSTICS.

By A. G. HUNTLEY

(of the May Construction Co., Ltd.).

II.

(*Delivered 23rd April, 1928*).

Acoustical problems divide themselves into two categories which, for want of better names, we will call Primary and Corrective: the first, of course, referring to the problem in connection with new buildings and the latter to existing ones. Both involve the same principles and, as was said in the last lecture, the provision of correct acoustic conditions calls for consideration of the shape of the building, its dimensions, the finish applied to its interior surfaces, and its furnishings.

In corrective work, the shape and dimensions are fixed and it is usually impracticable to alter them, so that only the surface finishings and furnishings are available for alteration. As these, however, are big factors in the control of reverberation, an excess of which is the cause of a large percentage of defective conditions, in most cases requiring corrective treatment a satisfactory solution can be found.

In new buildings, shape and dimensions can be fully considered, though in this direction the acoustical engineer is often placed in a rather delicate position, for he is not in the same happy position of, say, the steel-work designer who can fit his steel-work to any design and make a good job of it. With Acoustics it is not possible to make all and every design perfect.

The general architectural attitude with regard to Acoustics is—"there is my design, you fix it for acoustics;" and, with one reservation, I believe this to be correct, for any material alteration in a preconceived design may very well upset its whole character.

The reservation to be made is that the acoustics of a proposed building must be considered as soon as the sketch-plan stage is complete and before any other considerations, such as steel-work or ventilation, are taken into account; for, if then the shape of some surface seems fundamentally bad or if the cubic content is either too large or too small, there is a fair chance of an alteration being made. If the question is considered at a later stage, there is usually very little possibility of this happening.

If shape and dimensions cannot be altered, then all the Acoustic engineer can do is to point out the difficulty and then treat the problem as a corrective one by confining his attention to the surface finishings and furnishings.

In considering the question of shape, it is always unwise to copy some other building that is reputed to be good, as often very unlooked-for results may occur, because in an existing building, shape is only one factor. It was a case of this kind that was the *raison d'être* for the instructions to Prof. W. C. Sabine to take up his investigations, and it happened like this—a new Lecture Hall had been built at the Fogg Art Museum and, to ensure an acoustic success, it had been modelled on the lines of Saunders' Theatre, which was by far the best auditorium in Cambridge (U.S.A.); and the result was a complete failure. We now know that the reason was that the Lecture Hall was finished in hard plaster on brick tiles, whilst Saunders' Theatre was finished almost entirely in wood—at the time it was thought that only shape mattered. Again, it is not an easy matter actually to copy a shape; for example—as few halls have a flat ceiling, where should the height be measured? Particularly is this so in regard to the ratio of the length, breadth and height which one sometimes sees quoted, e.g., 5:3:2 or, what is known as the double cube, 2:1:1. If the building is not a perfectly regular figure, where should the measurements be taken? One writer who had seen the Mormon Tabernacle at Salt Lake City, a remarkably good auditorium, even recommended that all others should follow the same shape, namely, elliptical!

There are now, however, precise methods available for examination of the results that the shape of a proposed building will produce, so that all uncertainty is entirely removed. They are—

- (1) The Geometrical Method.
- (2) The Ripple-tank Method.
- (3) The Spark-pulse Method.

In the first of these a ray of sound is taken and it is assumed that its behaviour follows the same laws as a similar light ray (diffraction being ignored), i.e., that the angle of incidence equals the angle of reflection. Although this method is not dead accurate, owing to diffraction, yet it is extremely useful for preliminary work, for, should it reveal a complicated interference system, then it is at once evident that the more definite methods, 2 and 3, should be employed.

To appreciate this point, fully consider the following simple cases :—

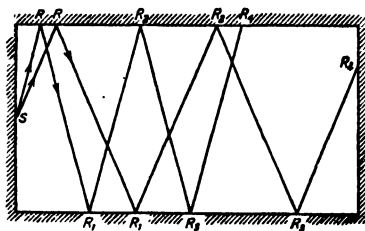


FIG. 2. Plan of Building.

Taking the plan of a plain, rectangular building, with a source of sound at S (Fig. 2) and plotting a pencil ray, as shown, it is found that it is reflected many times across the room from side to side. If, however, we slope the walls on the side of the source, as shown at AA, (Fig. 3), we get our ray reflected almost straight down the body of the hall, which, of course, makes for even distribution.

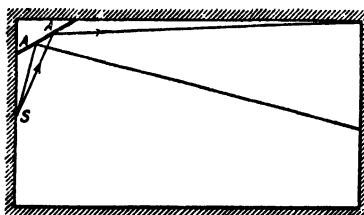


FIG. 3. Alternative Plan.

Fig. 4 is a longitudinal section of a rectangular hall having an overhanging gallery at one end. With the source at S, it will be seen that the gallery acts as a screen over the lower part of the hall, and prevents useful reflections from the ceiling reaching it. If, however, we slope the ceiling, as shown at AA

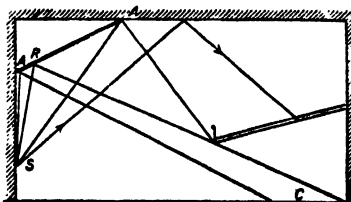


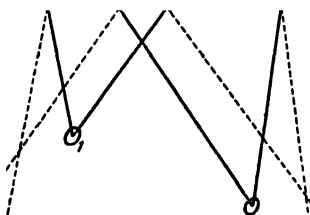
FIG. 4. Longitudinal Section of Hall.

above the source, then we can arrange to throw the sound right underneath the gallery, and, provided the path of the reflected sound, SRC, is not greater than SC by more than 70 ft. to 80 ft., excellent results will be obtained.

These two cases are, of course, very elementary, but they serve very definitely to show how even distribution is affected by the shape of bounding surfaces.

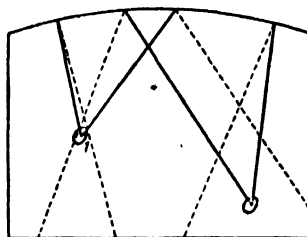
Now, suppose that our auditorium is a multi sided figure: it is obvious that we shall get reflections in all directions, and that these reflections will be constantly crossing each other, which will tend to produce patches of maximum and minimum sound, according to whether the reflections are reinforcing or destroying each other, so that further investigation should be made to discover whether adequate reinforcement might be secured from the ceiling, thus allowing the side walls to be made more reflective.

The following diagrams (Fig. 5) show the effect of various types of ceilings.



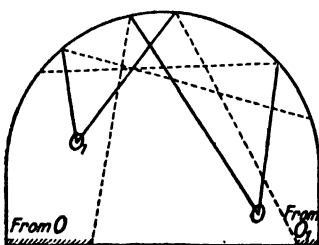
FLAT CEILING.

Showing how the sound from a source in any position is evenly distributed. O and O₁ are for a speaker at floor and gallery level.



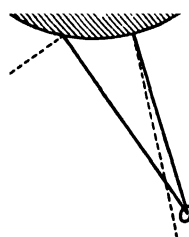
CURVED CEILING; radius twice the height.

Showing how a curved surface tends to concentrate sound after reflection. The reflecting areas are the same as for a flat ceiling, but the areas covered by the reflected sound are reduced by about 50 per cent.



BARREL VAULT.

Showing concentration caused by steep curves. Only hatched portion of floor receives reinforcement by reflection.



CONVEX SURFACE.

Showing the dispersal produced. Such surfaces can at times be usefully employed in ceiling coves, etc.

FIG. 5. Effects Produced by Various Types of Ceiling.

A flat ceiling, as would be expected, gives the most even distribution. Where a curved ceiling is employed, the more concentrated are the reflections

from it. In practice, where a curved ceiling must be employed, a safe rule is to use a radius of curvature of not less than twice the height of the ceiling. Spherical and barrel vault ceilings are nearly always dangerous.

THE RIPPLE-TANK.

The principle on which the ripple-tank is based is the great similarity between the propagation of sound waves in air and the surface waves in a small tank of water. Certain factors, such as viscosity and surface tension, enter into the latter case, but, as the dimensions and amount of water involved are so small, they can be ignored without appreciably impairing the accuracy.

Fig. 6 is an illustration of a ripple-tank with a wooden model in position. The ripple-tank consists of a rectangular wooden tank with a glass bottom containing about an inch of water. The model of the auditorium under consideration is placed in the tank and the plunger is adjusted to correspond with the position of the speaker. The plunger is withdrawn from the water by an electric magnet and thus a train of ripples is started. These spread outwards in the same way as sound waves, until they strike the edges of the model, where they are reflected. A strong light is placed underneath the tank in order more clearly to show up the ripples, by projecting their shadows on to a screen mounted above. In this way, it is possible to watch the way that sound will be propagated and reflected in a proposed building.

With a suitable electric timing device it is possible actually to photograph these at suitable intervals after their commencement.

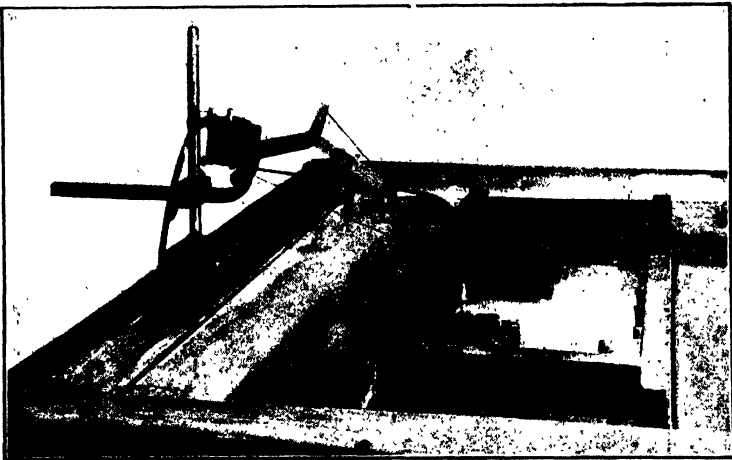


FIG. 6. National Physical Laboratory ripple-tank apparatus showing sectional model of auditorium in position*.

*Reproduced by kind permission of Messrs. G. Bell & Sons, from "The Acoustics of Buildings," by A. H. Davis, D.Sc., and G. W. C. Kaye, O.B.E., M.A., D.Sc., F.Inst.P.

The scale of the models usually employed is $\frac{1}{4}" = 1' 0"$.

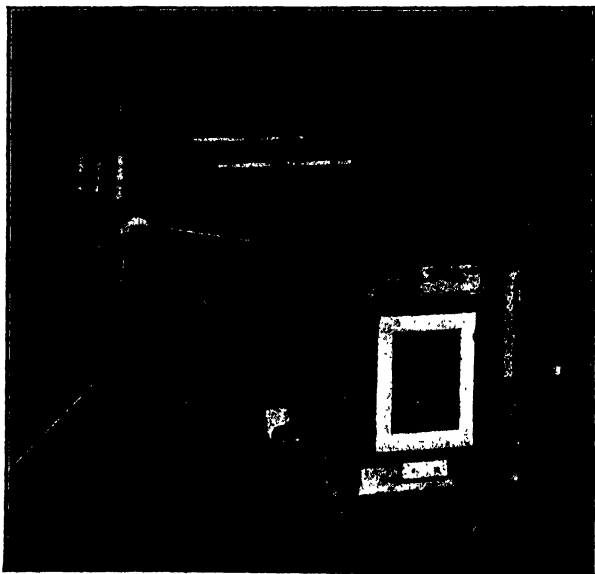
In the analysis of a ripple-tank photograph, it must always be borne in mind that a short train of waves exists and not just one pulse.

One other feature is worth noting, viz., that the sides of the tank are sloped or "beached," so that reflection can take place from them. This is necessary because, at times, it is essential to assume some area as being totally absorbent, as, for instance, would be the case in the floor of an auditorium with the full audience present. This condition is produced in the tank by removing the portion of the model representing the floor; in this way the ripples pass through the opening and pass on to the edge of the tank. Here, were the "beach" effect not present, they would be reflected back to the model again.

THE SOUND-PULSE.

To get a sound-pulse photograph requires a far more complicated apparatus, but—as it results in a very much clearer picture, because only one pulse is photographed and not a train of waves, as is the case in the ripple-tank—there is a good deal to recommend its use.

The main principle of the apparatus is that light is reflected by sound waves, thus causing shadows which can be photographed. Just exactly what this means can best be understood by comparison with a common phenomenon which everyone, at sometime or another, must have noticed. It is usual to place radiators under windows, and, any day when the sun happens to be shining through, dancing shadows are clearly visible above the radiator, provided, of course, that it is giving off heat. These shadows, "shimmerings" I believe



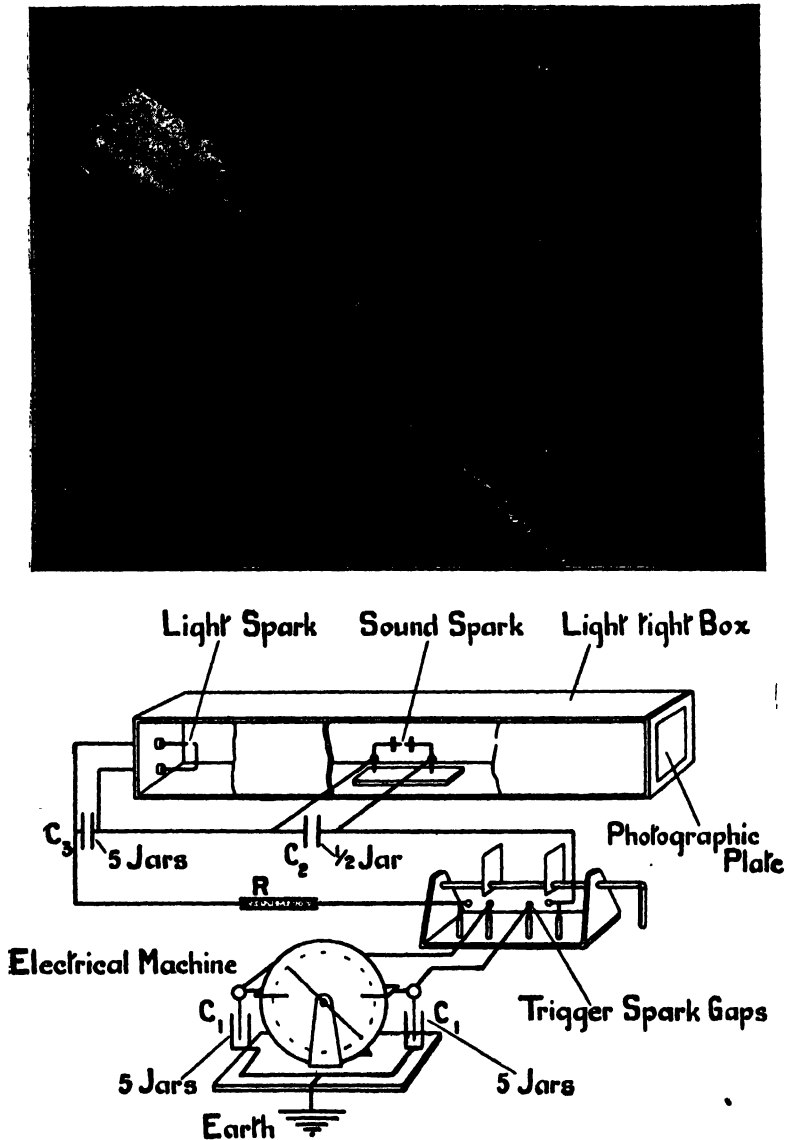


FIG. 7.*

they are popularly called, are caused through light being refracted by the convection currents rising from the radiator.

The following illustrations (Fig. 7) and description are taken from *The Acoustics of Buildings*, by Drs. A. H. Davis and A. W. G. Kaye, by their kind

*Reproduced by kind permission of Messrs. G. Bell & Sons, from "The Acoustics of Buildings," by A. H. Davis, D.Sc., and G. W. C. Kaye, O.B.E., M.A., D.Sc., F.Inst.P.

permission, and show the sound-pulse apparatus as used at The National Physical Laboratory.

The apparatus consists of a large electrical machine capable of generating a potential of about 100,000 volts which charges a battery of five Leyden jars C_1, C_1 on each side of the machine. By means of trigger spark-gaps the jars are discharged at will through the two spark-gaps marked "sound-spark" and "light-spark," both within a light-tight box. The sparks pass in the trigger-gaps when the glass plates shown are moved in or out of the gaps. The spark passing between the platinum electrodes of the "sound-spark" generates a sound-pulse—somewhat intensified by the small Leyden jar C_2 —and this is illuminated a small fraction of a second later by light from the delayed "light-spark," the delay being effected by means of a large condenser C_3 across the electrodes. The light-spark is enclosed within a small capillary tube, a point-source affording good definition being thus obtained. The electrodes are of magnesium, so that the illumination is especially brilliant and photographically active. The light from the light-spark casts a "shadow" of the sound-pulse upon a viewing screen or photographic plate at the end of the box. The model section of the building of which the reflecting characteristics are desired is made in ebonite or hard wood, usually to a scale of 1 in. to 32 ft. The sound spark-gap is suitably disposed within the interior of the section and at right angles to its plane.

Constancy in the behaviour of the apparatus is increased by passing a series of sparks at a regular rate for some time before the photographic negative is exposed. The liquid rheostat R , first suggested by Huguenard, improves the control of the longer time-intervals, although it somewhat enfeebles the sparks. In order to prevent fogging of the plate by light scattered from the inner surface of the box, the interior is painted dead black and is fitted with a series of diaphragms, the apertures of which increase from the light-spark to the plate. Light from the sound-spark is prevented from reaching the plate by projecting discs mounted on the electrodes.

The apparatus, as at present designed, is capable of giving photographs showing the progress of waves up to a time-interval corresponding to about one-eighth of a second in an actual full-size building, i.e., to a path distance of, say, 150 ft.

The following illustration shows the results obtained from (a) the sound-pulse apparatus, (b) the ripple-tank; the time interval in the two corresponding almost exactly. As will be seen, the sound-plate is very much clearer for reasons already explained, but the two show a most striking resemblance.

From the study of such photographs it can be decided whether the reflections from any given surface are going to be useful or detrimental and, should the latter prove to be the case, then it will have to be decided whether they can in any way be conveniently altered or whether it will be possible to minimise their effect by making them absorbent.

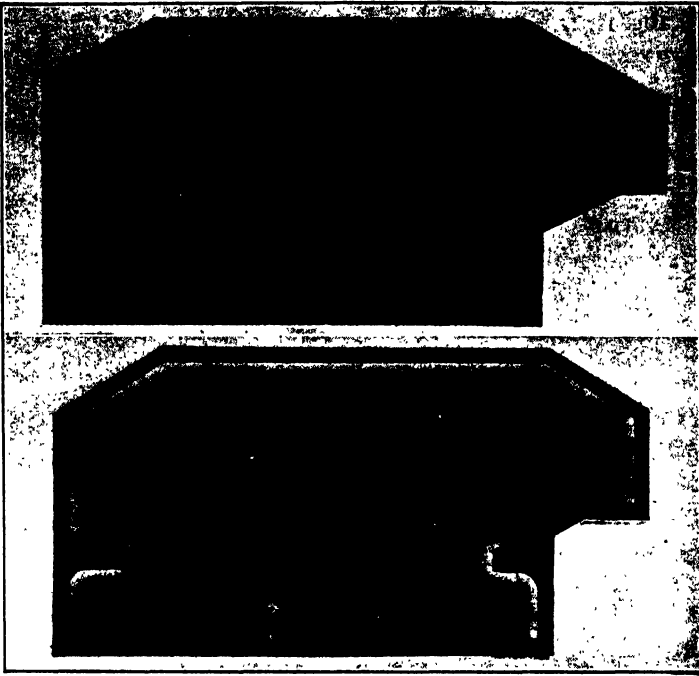


FIG. 8*. Comparative studies showing resemblance between sound-pulse and ripple photographs for similar model sections.

Sabine has shown that reverberation is dependent on the cubic contents of the building as well as on its absorbing power. If, then, when the figure has been calculated, it is found to be either too long or too short, one method of rectification is an alteration in its dimensions either to increase or reduce its cubic capacity. In a general way the reverberation is more likely to be excessive, so that reduction is likely to be indicated, and this, as representing a saving in cost would, in these days, be generally welcomed.

Before these principles are considered with regard to design, the various highly-absorptive materials must be reviewed. These fall into two main groups which will be termed soft and hard. From these definitions, it is recognisable that the probability is that the soft are acoustically more efficient than the hard, and this, indeed, is the case. The hard, however, have certain structural advantages which often counter-balance their relatively low absorption.

From a practical point of view these two groups contain three and two materials respectively ; these are :—

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Soft	{	Felt.
		Cabot's Quilt.
		Slag Wool.
Hard	{	Acoustic Plaster.
		Acoustic Artificial Stone.

There are certain other materials, having generally higher coefficients than ordinary building materials; but these are not included here because, from one cause or another, they are not commercially practical.

With regard to the relative merits of the above materials, Felt has the highest coefficient, though it is only some 5% in excess of the next one (Cabot's Quilt). In talking of Felt in this connection, special Acoustical Felt 1 in. thick is meant. This is a very closely woven material and is extremely expensive not only to buy but to fix as well.

Cabot's Quilt, on the other hand, is cheap to buy and moderately cheap to fix. It consists of a matting of seaweed (*Zostera Marina*), commonly known as Eel Grass. This Grass, which is gathered round the coast of Nova Scotia and Newfoundland, is packed and quilted in between two pieces of strong brown paper, and is made in continuous rolls of about 100 ft. Hence the cheapness of fixing and the elimination of waste. From the physical point of view, too, Cabot's Quilt has much to recommend it; for it is commercially fireproof in that it will only char in the presence of flame and will not in any sense carry or spread fire. It is not "treated" in any way, so that the effect cannot wear off. Earwigs, spiders or other vermin, will not live in it either; and here, again, the effect does not wear off. The reason for these properties is that in "Eel Grass" Silicon replaces, to a large extent, the carbon content of plants that grow in the air; moreover, like many other seaweeds, it contains iodine. Lastly, wet or dry, it is not subject to decay. At the present time, samples of the Grass are in existence that are over 200 years old. If it has a fault, it lies in the paper covering which, the physicists contend, is resonant under certain circumstances.

Slag Wool has also a high value, but is not very much used for Acoustic work, owing to the fact that it invariably settles down, thus creating unabsorbent spaces.

The method of using these three materials is much the same in each case. Wooden grounds are first of all fixed to the surface to be covered and the Felt or Cabot's Quilt is then nailed to them. In the case of Slag Wool, wire netting of small mesh is fastened to these wooden grounds, the material being then packed in behind.

The materials cannot, of course, be left like this, and so further wooden battens are placed on top, the whole area then being screened by having a canvas casement cloth or tapestry stretched in front of it. With regard to this covering, it must be borne in mind that the thicker it is the more resistance will it offer to the sound waves passing through, which they must do if they are

to be adequately absorbed. Where a plain canvas covering is used, a decorative effect can be obtained by distempering.

The soft materials are of special value in existing buildings as they make very little mess and are quickly handled. In new buildings, where these two points do not count for much, architects often consider that the canvas finish is not sufficiently durable (though it is undoubtedly good for many years) and they therefore prefer one of the hard materials.

The two hard materials, although their acoustic value is appreciably less than the soft group, have considerable structural advantages and can, where properly handled, be made to fit in and harmonise well with almost any design. Both of them have, and must have, an open texture, the stone being rather like Ham Hill Stone or, to use a more homely example, Scotch Oat-cake. Acoustic Plaster has a rather similar texture, though it is rougher and not so open as it has to be applied like ordinary plaster and, therefore, must be sufficiently plastic not only to spread but to adhere. Consequently, it is rougher and denser than pressed pre-cast stone which has time to mature before being used in the building.

In order to illustrate the application of Acoustical principles to design, it will be best to take some concrete examples. The following is a very simple case :—

A proposed auditorium is required to seat 300. It is rectangular in plan, measuring 70 ft. by 30 ft., with a stage or rostrum at one end, no gallery being required. The building is to be used primarily for speech, but occasional concerts will be held in it. From the dimensions given it will be seen that the first essential of adequate loudness will easily be fulfilled, as any speaker will be able to create sufficient volume of sound to completely fill it.

The next consideration will be that of even distribution of the sound over the floor space. Here, again, owing to the simple shape of the bounding surfaces, no very complicated interference system can be set up through multiplication of reflections. The longest reflected paths of sound will come from the wall opposite the platform, and will measure 140 ft. or twice the length of the building, so that one-eighth of a second will elapse between a syllable being uttered by a speaker and its return to him from the back wall. This will give the impression of the voice being thrown back from this wall, but not sufficiently pronounced to give a distinct echo. This point should be remembered when the question of the reverberation is considered, for, should it be found necessary to introduce absorptive material, it is clear that a good place to put it would be on the back wall, to minimise the reflections from this surface.

Up to the present, no reference has been made to the ceiling, but, if the architectural features of the hall permit, a flat ceiling, as already pointed out, will not only make for even distribution of sound, but also provide for the maximum reinforcement being given to the audience by reflections from it.

Assuming the height is temporarily fixed at 40 ft., the requirements of reverberation must be investigated. As the building is required primarily for speech, with occasional music, we can say a reverberation of $1\frac{1}{2}$ would be suitable for the full hall.

Now, from the Sabine formula of

$$t = \frac{.05V}{r}$$

if $t = 1\frac{1}{2}$ and $.05V = 4,200$, then r must $= 2,800$; that is, the total absorbing power of the room must be 2,800 open window units in order to obtain a reverberation of $1\frac{1}{2}$ seconds. Towards this total absorbing power of 2,800 we have—

		Units.
Audience	300×4.7	$= 1,410$
Wood floor, 70 ft. x 30 ft. ...	$2,100 \times 0.05$	$= 105$
Plaster walls and ceiling ...	$10,100 \times 0.025$	$= 252$
Making a total of		$1,767$

For simplicity's sake the area of glass has been ignored, and the window openings taken as being entirely covered over with plaster.

But we require 2,800 to give us our correct reverberation, so that, if the assumed volume is essential, then we shall have to introduce 1,033 units. This could easily be done by employing one of the highly absorbent materials—such as Cabot's Quilt, acoustic plaster, or hair felt—and this would mean in square feet an area of—

$$(1) \quad 1033 \div 0.60 = \frac{1033 \times 5}{3} = 1720 \quad \text{if Cabot's quilt is employed}$$

(the coefficient of absorption of quilt being 60% open window units).

$$(2) \quad 1033 \div 0.30 = \frac{1033 \times 10}{3} = 3443 \quad \text{if acoustic plaster is used}$$

(the coefficient of plaster being 30% open window units).

Further, if Cabot's quilt were adopted, the whole of this could be placed on the back wall of the building; and it would serve, if fixed there, not only to reduce reverberation, but also to prevent effectually sound being reflected from this wall to the annoyance of the speaker and the occupants of the front seats.

If, on going into the question of the volume again, it is found that the height of 40 ft. might conveniently be reduced to 30 ft., then this would reduce the total absorbing power of the auditorium to 2,100.

From calculation on the above figures, R would then be—

								Units.
Audience	...	...	...	...	...	...	...	1,410
Wood floor	...	...	...	...	...	...	...	105
Plaster	...	...	...	...	...	...	...	202

Which gives a total of 1,717

This would only leave 383 units to be supplied by the particular absorbent decided on, as against 1,033 units in the first case.

So far no value has been allowed for the actual seats, which may vary from 0.1 for chairs to 1 for, say, upholstered seats, the reason for the omission being that the case under consideration was that of the Hall with its full complement of audience, for which the full allowance of 4.7 units per person was taken. Had the calculations first been based on the empty hall, then allowance would have been made for the seats, but this allowance would, of course, have had to have been deducted from the 4.7 units per person. The supposition is that the effect of the seat was neutralised by a person sitting in it.

Up to now we have only considered the question assuming the hall to be entirely filled. It may, however, often happen that the average attendance is, say, half the maximum capacity, so that the reverberation must be adjusted on these lines. Where possible, then, it is desirable that the audience should make little or no difference to the absorptive power of a building. That is, they shall take away by screening approximately the same number of units as they themselves are supplying. Thick carpets and heavily upholstered seats are the best means of arriving at this desirable state of affairs.

In existing buildings treatment will fall under two headings—structural and physical—or what may be termed surgical and medical. The former, for obvious reasons, can only be resorted to in very extreme cases, when the interference system is setting up abnormal zones of maximum and minimum sound. Structural work to alter the contours of a building is not a task which may be lightly undertaken.

In very many cases, however, it will be found that the chief cause of trouble is excessive reverberation, and this fortunately may be readily corrected. When plans of the building are available, the volume and the surface area of its bounding walls can be obtained, and this figure can be checked by actual measurement in the building itself. From these data can be calculated the number of units of absorption that must be added in order to obtain an acceptable period. These extra units can be supplied by introducing absorbent materials, whilst a study of the building will soon reveal the best place for fixing them, so that they may not only reduce reverberation, but also cut out any reflections that might militate against even distribution, or the production of echo.

In really large buildings, in which definite echoes exist, the finding of the surfaces causing the echo or echoes is very interesting work. The instrument necessary is a large reflector, usually parabolic in form, with a source of sound suitably mounted inside. The reflector and the source are mounted so as to throw out or project a beam of sound. In fact they are arranged in much the same way as a motor-car headlight. This sound projector, as we will call it, is mounted at the position usually occupied by the speaker or singer. It is then turned in various directions until an echo is noticed; then the sounding instrument is removed and either a sight taken through the back of the reflector or else an electric lamp, to project a beam of light, is substituted. Either way the exact surface of the building towards which the projector is pointing, and which must have been primarily responsible for producing the echo, is revealed. The word "primarily" is used advisedly, because the sound may have been reflected two or three times before an observer hears the echo. Thus an echo may be heard coming from one side of a building whilst the surface primarily responsible for causing it is actually on the other side. The elimination of echo is always more successful when the primary reflecting surface is discovered and made absorbent.

There is one other point that, so far, has not been discussed, and that is electrical amplification. This has been purposely left over, for, except in the very largest of buildings, it should not be necessary. To secure the best results, such a system needs careful attention and constant supervision, but where, for one reason or another it has to be employed, then there is one cardinal rule.

Use a number of small loud speakers. Whispering speakers would perhaps be a better name for them. A large volume of sound in one place is not required, as this would only create worse confusion, particularly where excessive reverberation is the cause of the trouble in the first place. Small speakers 10-15 ft. from the ground, point downwards, and so arranged as to cover an area of 15-20 ft. diameter, will always give the best results.

WHISPERING GALLERIES.

All the really well-known Whispering Galleries that exist to-day are probably, without the slightest doubt, accidents, and, like most accidents, had they been intended they could have been improved upon. The most notable are: the Dome of St. Paul's Cathedral; the Salle des Carialesdes in the Louvre, Paris; the Ear of Dionysius, Syracuse; St. John Lateran in Rome; the Cathedral of Girgente, Sicily; and the Mormon Tabernacle, Salt Lake City. Of these St. Paul's will be of the most general interest, so let us see exactly what is the cause and what happens.

Many people will have actually seen the Gallery and will know that the Guide stands at one side, and placing his face close to the wall whispers softly. The best place for the observer is directly opposite the Guide, though at any

place on the circumference the whisper can be heard ; but the clearest point is certainly opposite the Guide.

The Gallery is, of course, circular in plan, and, if we take a section through it, we find that there is a stone bench running round the whole way and that the wall is inclining inwards over the bench. There is, moreover, about 20 ft. above the bench, a heavy stone cornice. If the Gallery were straight, we should get more or less three sides of a speaking box out of which most of the sound would escape through the missing side. As, however, the Gallery is circular, the intensification of sound is due to its accumulation when turned on itself by the circular wall. This accumulation is, moreover, intensified by the "lean" of the Gallery wall, which causes all sound passing the point midway between the Guide and the observer to be brought down to the head level of the observer with consequent general intensification.

Apart from the foregoing the Gallery is built of smooth stone with a stone floor, so that there is nothing to absorb the sound except the coefficient of the stone itself, and as this is very small, probably less than 2%, the whisper is almost as loud at the observer's side as at the guides.

NOTES ON BOOKS.

MEASUREMENT AND CALCULATION. By Norman Robert Campbell, Sc.D., F.Inst.P.
London : Longmans, Green & Co., Ltd. 12s. 6d. net.

The legitimate boundaries of physical science have in recent years been somewhat remarkably extended into a region which was formerly looked on as the domain of metaphysics. The change is due not so much to any question of definition, as to the discovery that experimental observation is capable of furnishing evidence relating to problems which had been considered to be subjects for purely abstract speculation.

While the main advance in this direction is that which has been associated principally with the name of Einstein, there has not unnaturally resulted a rapid growth of interest in the whole borderland of physics and metaphysics. For the physicist as such, the test of relevance must, as indicated above, be whether the problem can or can not be conceived of as one which is in any degree open to attack by experimental methods ; and many deplorable utterances on the "failure" of scientific conclusions to enshrine ultimate verities might have been averted if this test had been more generally applied.

Dr. Campbell, in his very interesting studies of the foundations on which physical measurement is based, has been fully alive to this consideration, and has taken pains to preserve the experimental point of view throughout. For example, he says of his chapter on Calculation : "To the mathematician all that I have said there will appear useless or worse than useless ; it would be fatal for him to hamper the free play of his imagination by considering whether every step in his argument can be related to physical conceptions."

The contents of the book are necessarily a little heterogeneous ; but any appearance of lack of balance is due merely to the fact that the various subjects receive attention in proportion rather to the omissions from physical text-books, than to

their intrinsic importance. The earlier part of the volume is devoted to discussions on the laws of number and measurement ; after this there are chapters on standards and factors ; errors, both of measurement and of numerical laws ; approximate and statistical laws ; the process and meaning of calculation ; and finally on the theory of " dimensions." In view of the vagueness with which this last subject is usually treated, many readers will find this the most interesting of all the discussions.

In reading a book of this kind, it is inevitable that one should feel from time to time that elaborate ingenuity is being expended in proving propositions the truth of which is a matter of common sense ; and the author himself remarks on one occasion : " . . . most physicists would find it much easier to avoid errors of the kind we are considering by the exercise of their common sense than by undertaking a full logical analysis of the physical relation involved in any numerical law which they proposed to subject to an algebraic process." To acknowledge the truth of this, however, is no disparagement of the value of the book. Most of Dr. Campbell's propositions are by no means of the immediately obvious order, and the reader who masters the contents of this volume cannot fail to find himself in possession of a number of new and valuable ideas.

ANNUAL REPORTS OF THE PROGRESS OF APPLIED CHEMISTRY Vol. XII : 1927
London : The Society of Chemical Industry. 7s. 6d. net.

So large a field is covered by this indispensable annual volume, whose contents range over the whole area of chemical industry, that it is impossible to do more than indicate its scope by a few typical extracts.

It is pointed out in an introductory section by Mr. A. J. V. Underwood, that the year 1927 was " marked by a steady development of the policy of amalgamation in the chemical and allied industries in Great Britain and other countries." The full effect of these " mergers " is, of course, still to be experienced, but it is at least worthy of remark that they strengthen the national bargaining power in relation to the international agreements by which the more important industries are, for good or evil, so largely governed.

Amongst other questions of international moment, that of tariff barriers was discussed at the World Economic Conference, held under the auspices of the League of Nations in May, 1927 ; and it is noteworthy that, while the general removal of such barriers was advocated by the Germans, this policy was opposed by our own Association of British Chemical Manufacturers.

Of interest to many readers will be certain remarks on the beet sugar industry in England, which showed considerable expansion during the year in question. We are told that the adverse weather conditions of 1927 were disappointing for the growers, and affected the enthusiasm for the new crop ; but the conclusion reached is that a substantial profit was still possible, and that it is unlikely that the future of the industry will be seriously affected. It will be remembered also in this connexion that an Advisory Board has been set up to deal with the question of river pollution in general. Research is proceeding actively on this point, and it is to be hoped that a real measure of success will be achieved. At all events, we are no longer likely, through sheer lack of psychological perception, to fall into a repetition of the errors of the Victorian age in this matter.

Those who are interested in the rapidly growing nitrogen fixation industry may note that the present yearly German production of fixed nitrogen is round about 500,000 tons, while our own country produces only 20,000 tons ; from which the reader may draw whatever moral he pleases. An important point to be noted here is that the arc process is being rapidly displaced by the Haber nitrogen-hydrogen

process, which provided the basis for most of the German production of explosives during the War. The Haber process has penetrated even into Norway, the original home and stronghold of the arc method.

It is remarkable that the consumption of electricity in Great Britain in 1927 exceeded that of 1926 by no less than 25%, and as 70% of the total output is used industrially, it is evident that we are witnessing the progress of a change of first-class economic and industrial importance.

These few extracts, however, fail to do real justice to the Annual, the 700 pages of which convey an enormous quantity of information at a very low price.

MEMOIRS OF A. WOLKOFF-MOUMONTZOFF. London: John Murray. 21s. net.

On the jacket of this book is a photograph of the author which explains many things. It represents a most handsome old gentleman with the sweetest expression, who is clothed in one of those vast fur coats out of which we nowadays expect to see looming the hard bespectacled and black-bearded face of a Bolshevik Commissar. Alexander Wolkoff-Mouromtsoff must have been an extremely engaging personality. He was good-looking, well-bred, talented. He was something of a painter and something of a critic. But he mainly breathed the atmosphere of circles in which neither art nor life are taken altogether seriously, though artists and philosophers are petted and patronized by the elegant folk who compose them. It would be a feat to grow up in a castle filled with art treasures and not pick up a little culture; but bearing a great name is not really a guarantee of any sort of integrity, nor is being acquainted with a whole bevy of operatic singers the equivalent of a degree in Fine Art—which is itself not the same thing as a streak of genius.

Mouromtsoff met, among a host of celebrities, Tolstoy. Of the greatest genius his country has produced he writes: "His intelligence was far from being exceptional." It seems to have come as a surprise to Mouromtsoff, as it does to many, that artists tend not to adopt a "sensible" attitude in their human commerce. But Tolstoy "not intelligent!" There follows the familiar pitying comment on "What is Art?" Perhaps Plato, as the author of the "Republic," might have been called unintelligent.

At any rate, however sound his views on "What is Art?" Mouromtsoff himself painted the most successful and atrocious pictures. Several of these are reproduced in the autobiography. Their literalism is quite overwhelming. They must have taken a long time and much patience to execute, and one cannot help admiring this kindly aristocrat for the courage with which he at one period earned a living by his brush. While various contemporary artists of the highest genius were for ever faced with the workhouse or the lunatic asylum, Mouromtsoff was getting five hundred guineas for a water-colour.

One of the photographic illustrations to the book is entitled "A part of the beautiful wooden house at Gloubokojé." As a matter of fact, the house is anything but beautiful, with its mass of incongruous features and apparent lack of unity; but one feels that a sort of luxuriance was what appealed to Mouromtsoff, both in social amenities and in art, and so one is not surprised at the misuse of the adjective. The luxuriant mentality is superbly summed up in the following paragraph:—"The news we received from Venice was not very pleasant. Aeroplanes were beginning to bombard the city, and our caretaker telegraphed that a bomb had broken the windows of our palace. I replied that she was to have them put in again, but after several days another telegram informed me that this was useless as any day the same thing might happen. So then I decided to send our maid Gina to Venice at once with an order to put the glass back, for I could not bear the idea of leaving my house open to the weather."

P.B.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, OCTOBER 22. Automobile Engineers, Institution of, at the Royal Technical College, Glasgow. 7.30 p.m. Mr. Leslie H. Hounsfield, Presidential Address, "The Integrity of the Technical Man."
 Illuminating Engineering Society, at the Chamber of Commerce, Birmingham. 7 p.m. Mr. J. L. H. Cooper, "An Investigation of Electric Lighting in the Engineering Industry."
 Mechanical Engineers, Institution of, Storey's Gate, S.W. 6.30 p.m. Mr. H. R. Steward, "Compressed Air for Mining and Industrial Purposes."
 University of London, at King's College, Strand, W.C. 5.30 p.m. Rev. W. R. Matthews, "The Basis of Dogma."
 5.30 p.m. Mr. C. A. Macartney, "Hungary."
 At University College, Gower Street, W.C. 5 p.m. Prof. E. B. Verney, "Urinary Secretion." (Lecture II.)
 5.30 p.m. Major-General Sir George Aston, "Nelson in Battle." (Lecture I.)

TUESDAY, OCTOBER 23. Arts, Royal Academy of, Burlington House, W. 4.30 p.m. Professor Arthur Thomson, "Anatomy." (Lecture VII.)
 Asiatic Society, 74, Grosvenor Street, W. 4.30 p.m. Mr. Abdullah ibn Yusuf-Ali, "Education in India: The New Outlook."
 Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Dr. Arthur T. Henderson, "Studies in Asthma and Related Diseases: Etiological Factors: Anaphylactic and Allergic Phenomena." (Harben Lecture.)
 University of London, at Bedford College for Women, Regent's Park, N.W. 5 p.m. Professor Mackie, "Queen Mary and King James." (Lecture II.)
 At King's College, Strand, W.C. 5.30 p.m. Sir Bernard Pares, "Contemporary Russia." (Lecture III.)
 5.30 p.m. Engineer-Captain Edgar C. Smith, "One Hundred Years of Naval Engineering." (Lecture II.)
 At University College, Gower Street, W.C. 5.30 p.m. Mr. L. St. Claire Grondona, "Australia and Empire Trade."
 Zoological Society, Regent's Park, N.W. 5.30 p.m. Scientific Business Meeting

WEDNESDAY, OCTOBER 24. Automobile Engineers, Institution of, at the Engineers' Club, Manchester. 7 p.m. Mr. Leslie H. Hounsfield, "The Integrity of the Technical Man."
 Egypt Exploration Society, at Burlington House, W. 5 p.m. Mr. C. J. Gadd, "Babylonian Seers and their Art."
 Mining Engineers, Institution of, at Burlington House, W. 11 a.m. Annual General Meeting. Dr. D. Penman, "Atmospheric Conditions in Indian Coal Mines." Messrs. C. C. Reid and A. V. Reis, "The Light given by various Types of Miners' Lamps." Mr. J. R. Homer, "The Sizing of Coal for Briquetting." Mr. T. Greenland Davies, "Extracts and Recommendations from the Report of the Water Dangers Committee." Mr. G. S. Rice, "Mine-Rescue Work in the United States."
 Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Dr. W. J. O'Donovan, "Occupational Cancer of the Skin."
 University of London, at the London School of Economics, Houghton Street, W.C. 6 p.m. Prof. L. R. Dicksee, "Some Comparisons in Office Machinery."
 At the School of Oriental Studies, Finsbury Circus, E.C.2. 5.15 p.m. Sir Wolsley Haig, "Wit and Wisdom in Persian Literature."

At King's College, Strand, W.C. 5.30 p.m. Dr. A. J. Allmand, "The Role of Chemistry in the Life of the Nation."

At the University Union Society's Rooms, Malet Street, W.C. 5.30 p.m. Mr. Julian Krzyzanowski, "Renaissance Poland." (Lecture IV.)

THURSDAY, OCTOBER 25. Antiquaries, Society of, Burlington House, W. 8.30 p.m.
 Chadwick Public Lecture, at the Royal Institute of British Architects, 9, Conduit Street, W. 5 p.m. Mr. Torben Grut, "Public Health Buildings and Recent Improvements in Town Developments in Sweden."
 Electrical Engineers, Institution of, Savoy Place, Victoria Embankment, W.C. 6 p.m. Lt.-Colonel K. Edgcombe, Presidential Address.
 Mining Engineers, Institution of, at Burlington House, W. 10 a.m. Continuation of Annual General Meeting.
 University of London, at Bedford College for Women, Regent's Park, N.W. 4.15 p.m. Prof. Eccles, "Pierre Cornille." (Lecture IV.) (In French.)
 5.15 p.m. Miss Tooley, "Travel as a Factor in Human Life." (Lecture I.)
 At King's College, Strand, W.C. 5.15 p.m. Mr. R. A. Jones, "Fénelon."
 5.30 p.m. Dr. Ernest Bullock, "Some British Songs."
 5.30 p.m. Mr. Ifor L. Evans, "The Old Kingdom: Economic Development."
 5.30 p.m. Mr. A. F. Meyendorff, "Social Legislation of the Soviet Government." (Lecture I.)
 At University College, Gower Street, W.C. 4 p.m. Dr. D. H. Scott, "Aspects of Fossil Botany." (Lecture II.)
 5.15 p.m. Prof. J. E. G. de Montmorency, "The Code of Theodosius."
 5.30 p.m. Miss E. Jeffries Davis, "Historical Factors of the Problem of London Traffic." (Lecture III.)
 At the University Union Society's Rooms, Malet Street, W.C. 5.30 p.m. Prince D. Svyatopolk Mirsky, "Tolstoy." (Lecture III.)

FRIDAY, OCTOBER 26. Arts, Royal Academy of, Burlington House, W. 4.30 p.m. Professor Arthur Thomson, "Anatomy." (Lecture VIII.)
 Chemical Engineers, Institution of, at the Institution of Civil Engineers, Great George Street, S.W. 6.30 p.m. Prof. Dr. A. L. Mellanby, "Fluid Jets and their Practical Applications."
 Mechanical Engineers, Institution of, Storey's Gate, S.W. 7 p.m. Mr. R. C. Macdonald, "Mechanical Plant in Gas Works."
 Physical Society, at the Imperial College of Science, South Kensington, S.W. 5 p.m.
 Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Dr. Arthur T. Henderson, "Studies in Asthma and Related Diseases—Clinical Studies of the Asthmias: (a) Simple or Uncomplicated, (b) Infective and Reflex, (c) Asthmatic Bronchitis." (Harben Lecture.)
 University of London, at King's College, Strand, W.C. 5.30 p.m. M. Denis Saurat, "Marcel Proust as a Novelist." (Lecture II.)
 5.30 p.m. Mr. William Poel, "Sejanus."
 At University College, Gower Street, W.C. 5 p.m. Prof. Dr. J. C. Drummond, "Recent Work on Vitamins." (Lecture III.)
 5.30 p.m. Dr. Thomas Ashby, "The Shores of Latium." (Lecture I.)
 At the University Union Society's Rooms, Malet Street, W.C. Prof. Dr. R. W. Seton-Watson, "The Collapse of Austria-Hungary." (Lecture III.)

SATURDAY, OCTOBER 27. L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Miss M. Edith Durham, "A Montenegrin Ballad of Old Tribal Life."

JOURNAL OF THE ROYAL SOCIETY OF ARTS

No. 3962.

VOL. LXXVI.

FRIDAY, OCTOBER 26th, 1928.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICE.

OPENING OF THE 175TH SESSION.

The Opening Meeting of the 175th Session will be held at 8.30 p.m. on Wednesday, November 7th, when the Inaugural Address will be delivered by SIR GEORGE SUTTON, Bt., Chairman of the Council. The subject will be "Fifty Years of British Industry."

After the delivery of the Address, the Society's silver medals awarded for papers read last session will be presented.

Tea and coffee will be served in the Library at the end of the proceedings

PROCEEDINGS OF THE SOCIETY.

CANTOR LECTURES.

ACOUSTICS.

By A. G. HUNTLEY

(of the May Construction Co., Ltd.).

III.

(Delivered 30th April, 1928).

The application of the foregoing principles is likely to be clarified by their consideration in relation to actual work, and in order to do this one building from each of the three groups will be taken in the following order :—

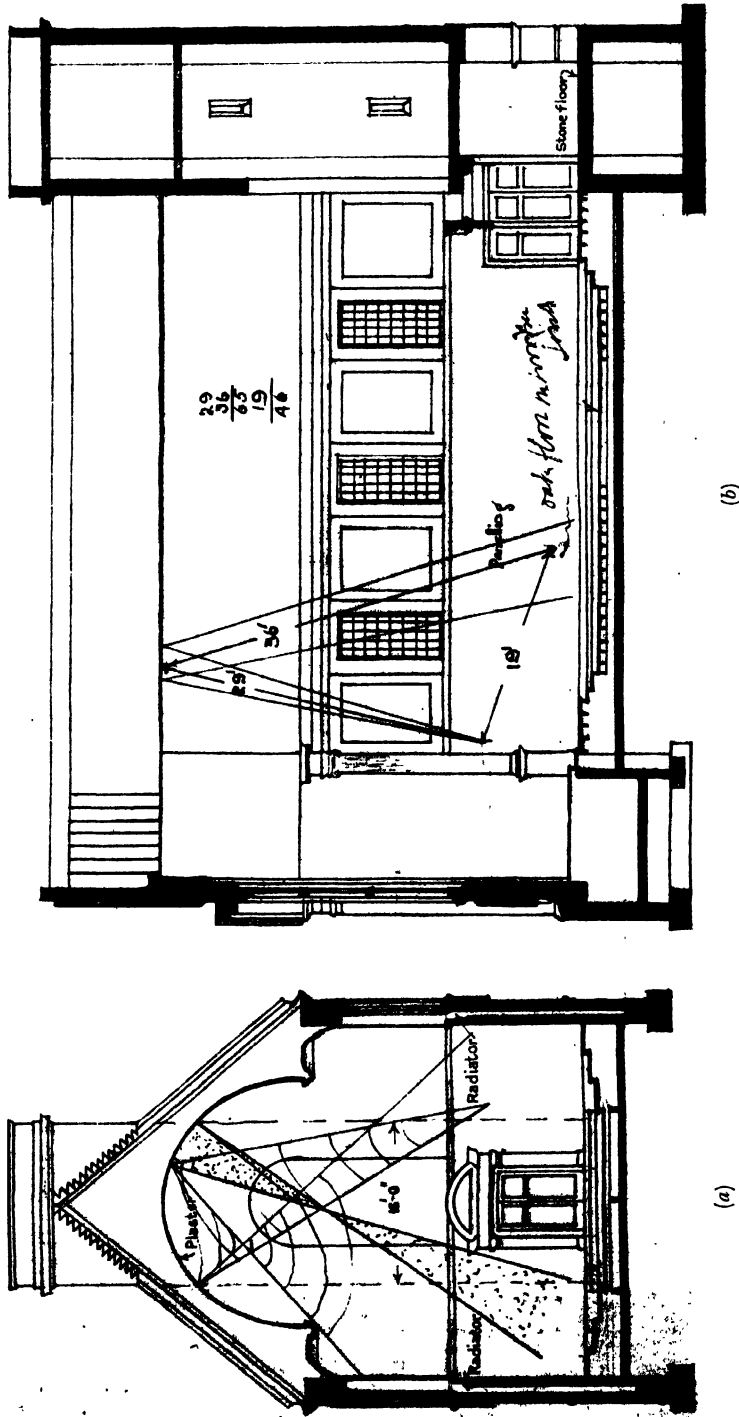


FIG. 9. Preliminary Sketch Plans. (a) Section, (b) Longitudinal Section,

Primary, i.e., calculations prepared in advance of construction.

Corrective, i.e., existing buildings.

Commercial, i.e., office, workshop and traffic noise.

PRIMARY.

The Chapel, Russell School, Ballards, near Croydon.

This building presented two somewhat unusual features :—

- (1) The organ was situated at the west end, whilst the pulpit, etc., were, of course, at the east; thus provision had to be made for sound sources at both ends of the building.
- (2) The pews were placed parallel to the longitudinal axis of the building and not in the more usual position at right angles to it.

Like all churches, the building was required for both speech and music, but it was desired that music should receive primary consideration. With this end in view a value of two seconds for the reverberation period, with 160 boys present, was decided upon. Before, however, the calculations for this period were made the shape required consideration

- (1) to discover whether the reflected sound would be evenly distributed over the ceiling area ;
- and (2) to decide what area, if any, was producing either non-useful or definitely harmful reflection.

Fig. 9 gives a cross-section of the building, and shows how certain portions of the barrel ceiling will distribute the reflected sound over the floor area. Pencil rays from the pulpit and from the centre of sound for the organ are shown. In both cases it is evident that the useful reflections appear to be obtained from the centre portion of the barrel, whilst non-useful ones are produced from the side. The word "appear" in the last sentence was used advisedly as it could not be said definitely that the reflections were useful until the horizontal section had been considered, because, although the cross section might show useful reflections, the longitudinal section might very well show these to be definitely harmful as echo producers. Here, however, in the worst case the difference between the direct and reflected sound rays is only some 50 ft., so that there is no danger.

So much for the shape. Now with regard to reverberation, the following gives the calculations in full :—

<i>Volume.</i>				<i>Absorbing Power (v).</i>			
57,994 cubic ft.	.05V =	2,900		Wood floor and panelling	4,130	sq. ft.	
<i>Absorption by Congregation.</i>				Plaster	6,172	„	
Value per boy	...	...	4.75	Glass	317	„	

Deduct for screening wood		Organ opening	123 ..
4 sq. ft. 2		4,130 x .05 = 206	O.W.U.
Deduct for boy 55		6,172 x .02 = 123	..
	— .75	317 x .01 = 3	..
		123 x .1 = 13	..
Nett value per boy 4.00			
	—		345 ..
			—

Value for 160 boys = $160 \times 4 = 640$ O.W.U.

$$\text{Reverberation Formula: } t = \frac{.05V}{r}$$

$$\text{Empty } t = \frac{2900}{345} = 8.1 \text{ secs.}$$

$$\text{Full } t = \frac{2900}{985} = 2.9 \text{ ..}$$

If "t" is to equal 2 secs., then "r" must = 1,450 units.

There are already 985 units, so that 465 more are wanted.

Acoustic Plaster has a coefficient of .3 units,

so that $\frac{465 \times 10}{3}$ sq. ft. (i.e., 1,550 sq. ft.) of acoustic plaster will provide the absorption.

Side ceiling panels		= 756	sq. ft.
Side wall panels		= 844	..
		—	
		1,500	..
		—	

Theoretical Value for "t" Empty Chapel:

$$t = \frac{2900}{810} \text{} = 3.6 \text{ secs.}$$

Actual value for "t" as measured

$$\text{after completion} = 3.45 \text{ ..}$$

Of this amount 756 sq. ft. was accommodated on the sides of the ceiling from which reflections were not required and the balance was applied to the walls in between the windows.

The illustration (Fig. 10) of the completed building shows how the ceiling was treated from the decorative point of view in order to make it possible to use both acoustic plaster and ordinary plaster on the barrel; the side panels, of course, being the acoustic plaster, whilst the centre is the hard plaster.

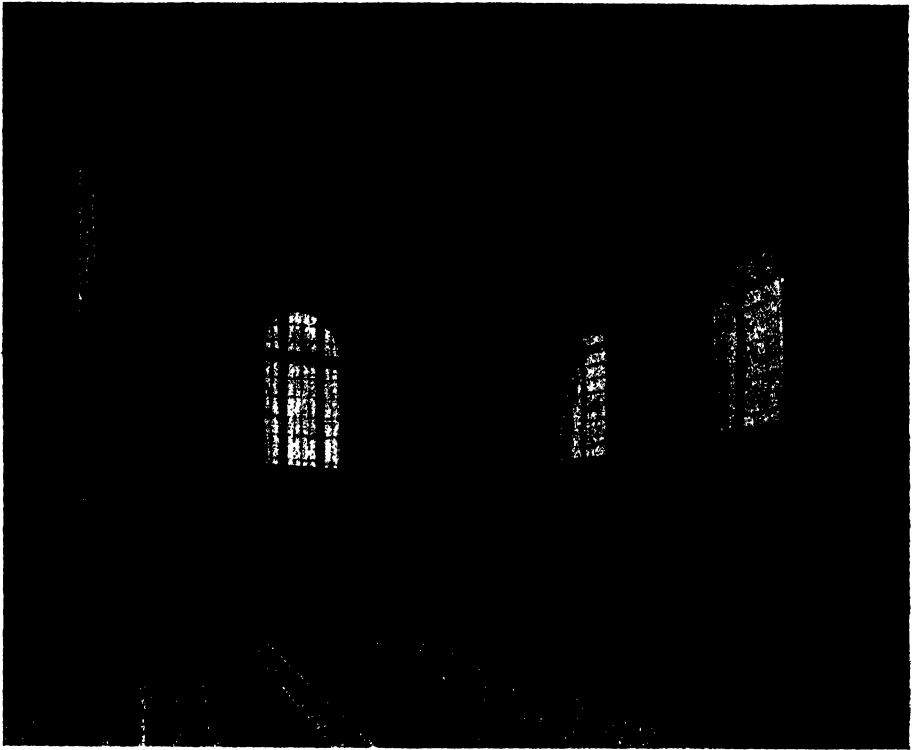


FIG. 10. Russell School Chapel.

CORRECTIVE.

The Council Chamber, West Riding County Council, Wakefield.

Here there was also one condition which seemed at first sight to be somewhat unusual, and this was that although there seemed not the slightest doubt that excessive reverberation was the cause of the trouble, yet the actual period when measured revealed it to be only 1.75 secs. in the empty building, which under ordinary conditions could not have been sufficiently long to have caused really serious and continued complaints.

In this case, however, investigation of the shape revealed the fact that the condition of adequate loudness was not being fulfilled because the direct sound was not being adequately reinforced by the reflected sound, for this, instead of being evenly distributed over the councillors' seats, was concentrated, by the shape of the ceiling, in patches, which, although they varied with the position of the speaker, were outside the area occupied by the seats. Thus a more or less normal period of reverberation was too long in this case. In this connection it must be remembered that speaking in a more powerful voice does not produce adequate loudness, because, although the initial intensity is

increased, so also is the period of reverberation, because there is more energy to be got rid of by absorption.

Another condition that had to be borne in mind was that there was very little difference between the reverberation figures for the empty and the full building. This condition was caused through the very heavy upholstery of the seats, the thick pile carpet, and the covering sheets that were always in position when the building was not in use. When the councillors took their seats the sheeting was, of course, removed, and the members themselves only contributed the same number of absorbing units as they were taking away by screening both the floor and the seats on which they sat.

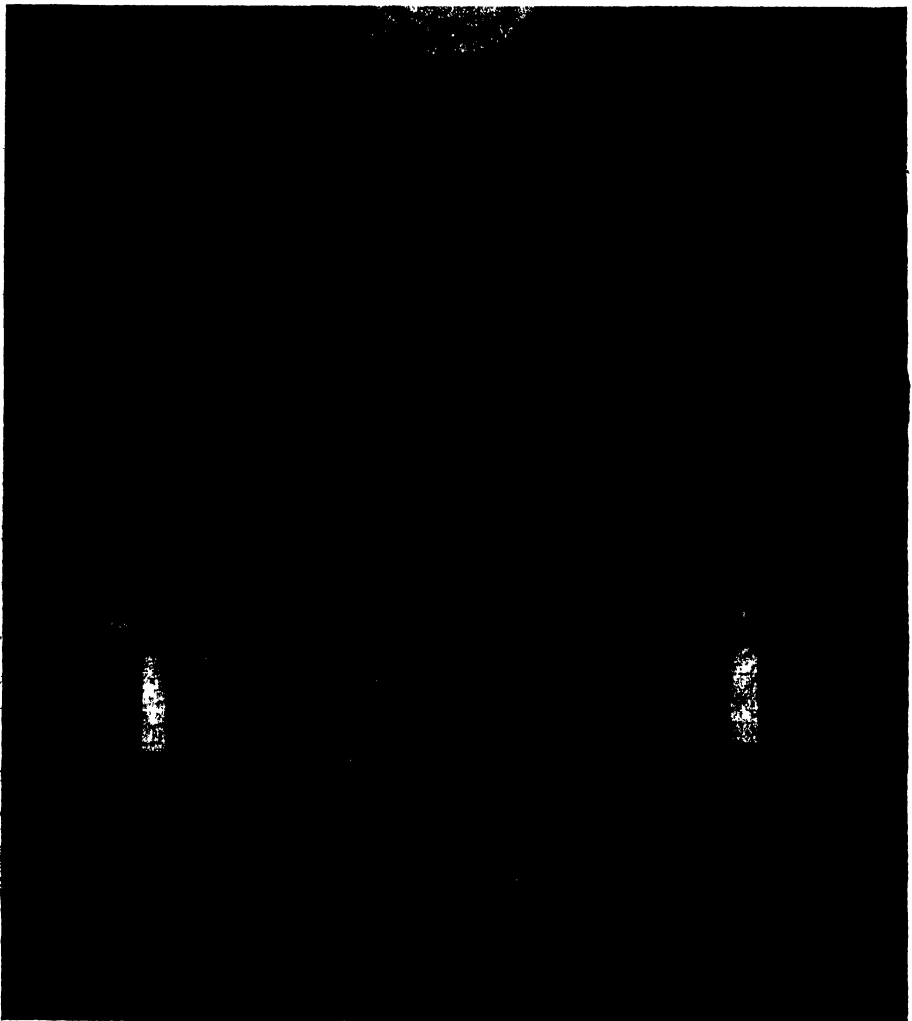


FIG. 11. West Riding of Yorkshire Council Chamber.

Accordingly, 2,000 sq. ft. of Cabot's quilt was introduced into the building. This gave some 600 units and had the effect of reducing the reverberation to just under 1 sec. After some three months' trial, the committee dealing with the matter was unanimous in its verdict that the acoustic defects had been entirely remedied.

The Cabot's quilt was mounted on wooden grounds and then screened with canvas, which was afterwards distempered to match the existing decorations. In this way the whole surface of the dome was covered as well as the recessed portion of the wall round the door opposite the chairman.

The above illustration gives a good general view of the building and shows a portion of the treated dome and the large recessed panel in the wall round the doorway.

COMMERCIAL WORK.

The Head Office of the Midland Bank, Ltd., Second Floor, Poultry, E.C.



FIG. 12. The Head Office (second floor) of the Midland Bank.

This building has been taken to represent this class of work because considerable trial work was undertaken before it was decided to install absorbent materials throughout the ceilings of the entire building.

The illustration shows the second floor office which contains a personnel of about 100, as well as some 80 adding machines and typewriters. At certain times of the day all these machines are in use, and sorting and "calling over" is going on at the same time. From past experience it has been found that in offices of this description noise is very intense, so that any method that offered a chance of reducing it was welcomed by the Bank.

In order, however, to be sure that the claims put forward could be substantiated, a small office was treated experimentally, and the results here appeared to the architects to be so satisfactory that they recommended a further experiment on a larger scale, and, accordingly, the ceiling of the first floor office was fitted with Cabot's quilt. This office was exactly similar to the second floor shown in the illustration. When this work was finished the directors came to inspect, and the chairman (the Rt. Hon. Reginald McKenna) expressed himself as so satisfied with the results that he gave instructions for the ceilings of the whole building to be similarly treated.

The other aspect of work in this category is the question of the reduction of traffic noise, and in this connection the following photographs taken by Prof. A. M. Low with his audiometer clearly shows what can be done in this direction.

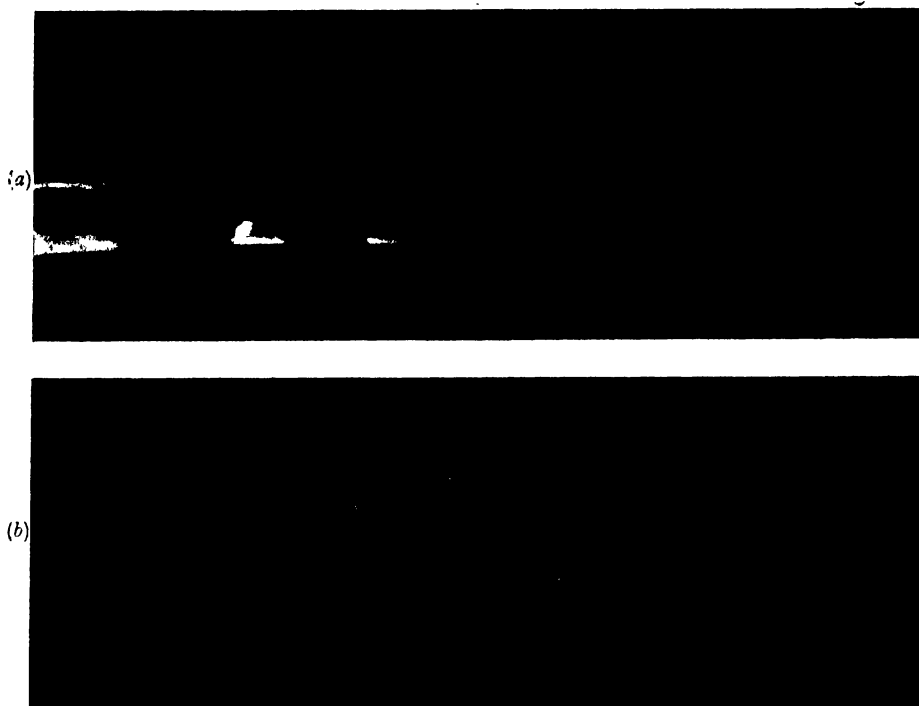


FIG. 13.

The photographs were taken in similar rooms in which the windows had been opened and the traffic noise was rising from Argyle Place, Regent Street, W.1.

(a) is the result obtained in the ordinary office, and shows the considerable agitation of the diaphragm of the instrument due to the incoming noise.

(b) is the result obtained in the adjacent room in which the ceiling had been made absorbent by the use of Cabot's quilt.

As the photograph shows, the difference is very marked, as an almost straight line is registered, thus showing that the noise in this case hardly possessed sufficient intensity to move the diaphragm at all.

Lastly, no series of this kind would be complete without some indication of the cost of acoustical work. In this connection the cost per yard is of very little value as it is apt to give an erroneous impression that the cost is practically prohibitive. The only cost that really matters is the cost per job, or, in other words, the answer to the architect's question: "How much has got to be spent to ensure correct conditions on my job?" And the best answer that can be given to such a question is to give the approximate costs of the three jobs already mentioned.

The Chapel, Ballards	...	...	...	...	£150
Council Chamber, Wakefield	...	...	...	...	£220
Midland Bank (Second Floor)	...	...	...	...	£250

These figures show how small the outlay really is. Had they been four or five times as great, even then, surely, that would not have been a high price to pay to ensure that the buildings were really suitable for the purpose for which so many thousands of pounds had been expended on their erection.

NOTES ON BOOKS.

DESCRIPTIVE ECONOMICS. By R. A. Lehfeldt. MONEY. By R. A. Lehfeldt. London: The Oxford University Press, Humphrey Milford. Each volume, 2s. 6d. net.

A series of small and conveniently arranged introductory treatises, termed "The World's Manuals," is represented by these booklets; the range of subjects included in the series being of broad interest or of high importance. To exemplify we may give a few of the titles as found in the list of manuals at the end of the second book under notice:—Sound and Symbol in Chinese, Greek Biology and Greek Medicine, Philosophy of Art, Our Minds and Their Bodies, Modern Political Theory. These small volumes, in convenient size for the hand or pocket, are evidently intended to open the door to those who may in time become profound students; a few leading aspects being presented in exact and academic form.

Thus Dr. Lehfeldt, who is professor of economics in the University of the Witwatersrand at Johannesburg, tells us nothing of the noisy contentions of political parties, but he commences by reminding us that farming is first or oldest among arts and industries and even now it is the most important industry. Improvement in

transport has effected great and various changes. The Russian farmer works almost like his ancestors of 200 years ago, but his living depends largely on eggs consumed in London, p. 10. We read of land-tenure and working conditions from China to the United States, with a thoughtful halt to consider the Prussian system, in which the landowner is the employer, and skilled well educated persons superintend. This naturally implies rather large farming units. Huge business farms are touched upon next, and the general principles of tenancy, sharing and otherwise, pp. 15-18.

Mining, factories, social relations, transport, commerce, and Governmental duties or functions are considered in the same spirit of limitation, exactness and suggestiveness; the well-considered and orderly bibliography crowning the whole by guiding the student to any required new path.

The second book under notice, in which Dr. Lehfeldt treats of money, has general merits similar to those of the first. It may also lead an advanced student to an understanding of facts in finance which are obscure in our usual books. Thus on p. 19 we see a tabulation of the gold available for money, at the conclusion of each ten years from 1851 to 1921. The increase in amount available is quite remarkable yet in no one of the great and prosperous countries is there any considerable amount of gold in circulation. This is explained fully and lucidly on pp. 19 to 32.

Dr. Lehfeldt leads us towards new shades of thought in economics, so all interested in the most vitally important of all sciences should study these books.

OBITUARY.

CECIL WEST DARLEY.—Mr. C. W. Darley, I.S.O., M.Inst.C.E., who died on October 18th, as the result of an accident, at the advanced age of 85, was the fourth son of Henry Darley, of Wingfield, Co. Wicklow. He was educated at King William's College, Isle of Man, and subsequently became a pupil of Mr. W. R. Le Fanu, who at that time was engaged on railway construction in Ireland. In 1864 he went out to New South Wales, where he was occupied at first with railway work, and afterwards with harbour works and water supply, being appointed in 1867 resident engineer of the Newcastle, N.S.W., harbour works, in 1889 engineer-in-chief for harbours and rivers, and in 1896 engineer-in-chief for public works for New South Wales. In 1901 he was appointed consulting engineer in London to the N.S.W. Government, and in 1907, after 40 years service, he retired, living at Bookham, Surrey. He had been a Fellow of the Society since 1904 and occasionally took part in discussions on engineering subjects at the Society's meetings.

GENERAL NOTES.

THE PHYSICAL SOCIETY AND THE OPTICAL SOCIETY. - NINETEENTH ANNUAL EXHIBITION.—The Nineteenth Annual Exhibition of Electrical, Optical and other Physical Apparatus is to be held by the Physical Society and the Optical Society on January 8th, 9th and 10th, 1929, at the Imperial College of Science and Technology, South Kensington. As on previous occasions the Exhibition will be divided into a Trade Section, comprising the exhibits of manufacturing firms, and a Research and Experimental Section. The preliminary invitation to trade exhibitors has already been issued, and the Exhibition Committee invites offers, from Research Laboratories and Institutions and from individual research workers, of exhibits suitable for inclusion in the Research and Experimental Section. The exhibits

in this section will be arranged in three groups:—(a). Exhibits illustrating the results of recent physical research; (b). Lecture Experiments in Physics; (c). Historical exhibits in Physics. Accommodation for these exhibits will be provided in rooms separate from those devoted to the trade exhibits; and a part of the catalogue will be devoted to their description. No charge will be made for space or catalogue entries in the Research and Experimental Section, and the facilities of the Imperial College will be at the disposal of the exhibitors. Offers of exhibits for inclusion in any of the above three groups should be communicated immediately, and in any case not later than November 14th to the Secretary, Physical and Optical Societies, 1, Lowther Gardens, Exhibition Road, London, S.W.7. Brief particulars of space and other facilities required should be given.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH. ENGINEERING RESEARCH. SPECIAL REPORT No. 7.—A report has just been issued by the Department of Scientific Research on "The Strength of Hexagon Nuts of less than Standard Size for Bright Steel Bolts." The report contains a description of tests made at the National Physical Laboratory upon hexagon nuts of less than standard size with a view to fixing some minimum size which might form the basis for the introduction of a new standard small size nut. These tests were made upon commercially produced bolts and nuts and a preliminary examination of the threads was made. The tests show that there is a well-defined limit of size at which the corners of the nut will give way before the bolt is stressed above its elastic limit. A comparison of this minimum size is made with the proposed new American standard for small nuts, with the recommendations of the British Engineering Standards Committee, and with the reduced sizes of large nuts used in Marine Practice as the result of experience. The report gives full particulars of the method of test adopted, together with particulars of the materials of which bolts and nuts were made. It also describes a few tests upon reduced sizes of hexagon heads of bolts, and vibration tests made in an endeavour to show whether or not the size of the nut had any effect upon the resistance to vibration. The report may be obtained, price 1s. 3d. net (postage extra) from H.M. Stationery Office, Adastral House, Kingsway, London, W.C.2, or through any bookseller.

MEETINGS OF OTHER SOCIETIES DURING THE ENSUING WEEK.

MONDAY, OCTOBER 29.—Electrical Engineers, Institution of, Savoy Place, W.C. 7 p.m. Discussion on "Our Profession from a Manufacturer's Point of View," opened by Lt.-Col. K. Edgcombe.

Illuminating Engineering Society, at 4, Fountain Street, Manchester. 7 p.m. Mr. J. L. H. Cooper, "An Investigation of Electric Lighting in the Engineering Industry."

Light and Heat in Medicine, Surgery and Public Health, Second International Conference on, at the University of London, South Kensington, S.W. 3.30 p.m. and 7.30 p.m. Afternoon Session, 3.30-5 p.m.: Dr. W. J. O'Donovan, "Actinotherapy in Nervous Affections of the Skin"; Dr. Franz Nagelschmidt, "A New Method of Applying Heat by Diathermy." Evening Session, 7.30-9 p.m.: Dr. W. Flaskamp, "Light and Heat in Gynaecology"; Dr. W. Kerr Russell, "A Consideration of Apparatus for the Production of Ultra-violet Rays for Medical Purposes."

University of London, at King's College, Strand, W.C. 5.30 p.m. Rev. E. J. Bicknell, "Dogmatic Pre-suppositions of the New Testament."

5.30 p.m. Prof. Dr. R. W. Seton-Watson, "Czechoslovakia."

At University College, Gower Street, W.C. 5 p.m.

Prof. E. B. Verney, "Urinary Secretion." (Lecture III.) 5.30 p.m. Major-General Sir George Aston, "Nelson in Battle." (Lecture II.)

TUESDAY, OCTOBER 30.—Arts, Royal Academy of, Burlington House, W. 4.30 p.m. Prof. Arthur Thomson "Anatomy." (Lecture IX.)

Electrical Engineers, Institution of, at the Hotel Metropole, Leeds. 7 p.m. Mr. F. S. G. Hinings, Chairman's Address.

At the Midland Hotel, Manchester. 7 p.m. Mr. J. Harcourt Williams, Chairman's Address.

Goethe Society, English, at King's College, Strand, W.C. 8.15 p.m. Dr. M. F. Liddell, "Ferdinand Freiligrath and his Time."

Light and Heat in Medicine, Surgery and Public Health, Second International Conference on, at the University of London, South Kensington, S.W. 3.30 p.m. and 7.30 p.m. Afternoon Session, 3.30-5 p.m.: Dr. C. B. Heald, "The Development of New Electro-therapeutic Apparatus"; Dr. Franz Nagelschmidt, "Foam Treatment." Evening Session, 7.30-9 p.m.: Dr. M. J. Dorcas, "Distribution of Energy from Various Types of Arcs."

Public Health, Royal Institute of, 37, Russell Square W.C. 4 p.m. Dr. Arthur T. Henderson, "Studies in Asthma and related Diseases" (Continuation of Clinical Studies). Harben Lecture.

Royal Institution, 21, Albemarle Street, W. 5.15 p.m.

- Prof. H. L. Callendar, "The Change of State from Liquid to Vapour."
 University of London, at Bedford College for Women, Regent's Park, N.W. 5 p.m. Prof. Mackie, "Queen Mary and King James." (Lecture III.)
 At King's College, Strand, W.C. 5.30 p.m. Sir Francis Younghusband, "Philosophy, Science and Religion."
 5.30 p.m. Sir Bernard Pares, "Contemporary Russia" (Lecture IV.)
 5.30 p.m. Engineer-Captain Edgar C. Smith, "One Hundred Years of Naval Engineering." (Lecture III.)
- WEDNESDAY, OCTOBER 31.** British Academy, at the Civil Service Commission Buildings, Burlington Gardens, W. 5 p.m. The Right Hon. H. A. L. Fisher, "The Whig Historians." (Annual Raleigh Lecture.)
 Central Asian Society, at Burlington House, W. 5 p.m. Mr. Eric Teichman, "The Peking Lhasa-Road."
 Faraday Society and the Electroplaters' and Depositors' Technical Society, at the Northampton Polytechnic Institute, St. John Street, E.C. 8.15 p.m. (1) Messrs. D. J. Macnaughtan and A. W. Hotherhall, "The Causes and Prevention of Pitting in Electro-deposited Nickel"; (2) Mr. S. Wernick, "On the Effect of Colloids in the Electro-Deposition of Silver from Silver Nitrate Solutions"; (3) Messrs. D. J. Macnaughtan and A. W. Hotherhall, "The Hardness of Electro-Deposited Nickel"; (4) Mr. Edward B. Sanigar, "Investigations on the Electro-Deposition of Silver."
 Illuminating Engineering Society, at Dial House, Northumberland Street, Newcastle. 7.15 p.m. Mr. J. L. H. Cooper, "An Investigation of Electric Lighting in the Engineering Industry."
 Literature, Royal Society of, 2, Bloomsbury Square, W.C. 5 p.m. Ordinary Meeting.
 Light and Heat in Medicine, Surgery and Public Health, Second International Conference on, at the University of London, South Kensington, S.W. 3.30 p.m. and 7.30 p.m. Afternoon Session, 3.30-5 p.m.: Dr. F. Talbot, "Actinotherapy and Dental Caries"; Dr. A. J. Cemach, "U-V Therapy in Oto-rhino-laryngology." Evening Session, 7.30-9 p.m.: Sir Henry Gauvain, "Heliotherapy and Artificial Light Treatment in Surgical Tuberculosis"; Dr. M. Weinbren, "Ultra-violet Radiation in the Treatment of Chronic Pulmonary Tuberculosis."
 Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Dr. S. W. Fisher, "Pains and Pleasures of a Miner's Life."
 United Service Institution, Whitehall, S.W. 3 p.m. Admiral Sir R. G. O. Tupper, "The Part of the Retired Officer in the Future of the Empire."
 University of London, at King's College, Strand, W.C. 5.30 p.m. Prof. Ernest Wilson, "The Indebtedness of Industry to Pure Science." (Lecture III—"Electrical Science and Industry.")
 At the London School of Economics, Houghton Street, W.C. 6 p.m. Mr. Gilbert Wood, "The New Toute-Automatique Madas."
 At the University Union Society's Rooms, Malet Street, W.C. 5.30 p.m. Dr. Julian Krzyzanowski, "Renaissance Poland." (Lecture V.)
- THURSDAY, NOVEMBER 1.** Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m. Mr. W. D. Douglas and Miss C. B. Pettifer, "The Testing of Adhesives for Timber."
 Antiquaries, Society of, Burlington House, W. 8.30 p.m. Auctioneers' and Estate Agents' Institute, 29, Lincoln's Inn Fields, W.C. 7.30 p.m. Sir H. Trustram Eve, "Rating—the Ground of Unfairness."
 Chemical Society, Burlington House, W. 8 p.m.
 Electrical Engineers, Institution of, at the Municipal College, Suffolk Street, Birmingham. 7 p.m. Dr. S. Z. de Ferranti, F.R.S., "Electricity in the Service of Man." (Faraday Lecture.)
 Illuminating Engineering Society, at 25, Bath Street, Glasgow. 7.30 p.m. Mr. J. L. H. Cooper, "An Investigation of Electric Lighting in the Engineering Industry."
 Light and Heat in Medicine, Surgery and Public Health, at the University of London, South Kensington, S.W. 3.30 p.m. Afternoon Session, 3.30-5.30 p.m.: Dr. Albert Eldinow, "Photosensitization"; Dr. C. Conyers Morrell, "Plant Pigments in Relation to Photosensitization"; Mr. T. C. Angus, "The Efficiency of Ultra-violet Light Producers."
 L.C.C. The Geffrye Museum, Kingsland Road, E.2. 7.30 p.m. Mr. W. G. Bell, "The Tower of London."
 Mechanical Engineers, Institution of, at the Royal Technical College, Glasgow. Eng.-Commander J. B. Sidgwick and Dr. V. E. Pullin, "Steel Castings." (Joint Meeting with Scottish Branch, Institute of British Foundrymen.)
 At the Engineers' Club, Manchester. 7.15 p.m. Mr. A. B. Mallinson, "An Up-to-date Cotton Mill Power Plant."
 At the University of Leeds. 7.30 p.m. Mr. B. H. Thorp, "Gaseous Explosions."
 Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Captain G. Pitt-Rivers, "Race and Culture."
 University of London, at the Royal Society of Medicine, 1, Wimpole Street, W.1. 5 p.m. Prof. Markusz Hajek, "Laryngo-Rhinology and General Medicine."
 At Bedford College for Women, Regent's Park, N.W. 4.15 p.m. Prof. Eccles, "Pierre Corneille." (Lecture V.)
 5.15 p.m. Miss Ellis-Fermor, "Travel as a factor in Human Life." (Lecture II.)
 At King's College, Strand, W.C. 5 p.m. Dr. W. Robson, "Protein Metabolism." (Lecture I.)
 5.15 p.m. Paul Vaucher, "Saint-Pierre."
 5.30 p.m. Mr. G. B. Harrison, "Bunyan's Life and Personality."
 5.30 p.m. Prof. Dr. R. W. Seton-Watson, "Transylvania (to 1914)."
 5.30 p.m. Mr. A. F. Meyendorff, "Social Legislation of the Soviet Government." (Lecture II.)
 At University College, Gower Street, W.C. 4 p.m. Dr. D. H. Scott, "Aspects of Fossil Botany." (Lecture III.)
 5.15 p.m. Prof. J. E. G. de Montmorency, "The Barbarian Codes as illustrating Social Life in Central and South-Western Europe from 450-750 A.D." (Lecture I.)
 At the University Union Society's Rooms, Malet Street, W.C. 5.30 p.m. Prince D. Soyatopolk Mirsky "Tolstoy." (Lecture IV.)
 Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Mr. Eric Maclagan, "The Forerunners of the Renaissance."
- FRIDAY, NOVEMBER 2.** Arts, Royal Academy of, Burlington House, W. 4.30 p.m. "Anatomy." (Lecture X.)
 Chemical Industry, Society of, at Manchester. 7.30 p.m. Sir John E. Russell, "Application of Chemistry in Modern Farming."
 Engineering Inspection, Institution of, at the Royal Society of Arts, Adelphi, W.C. 5.30 p.m. Mr. A. H. Munday, "Die Casting."
 North-East Coast Institution of Engineers and Shipbuilders, at the Mining Institute, Newcastle-upon-Tyne. 6 p.m. Mr. E. G. Barillon, "From Theoretical Hydrodynamics to Practical Ship Design."
 University of London, at King's College, Strand, W.C. 5.30 p.m. M. Denis Saurat, "Marcel Proust as a Novelist" (in French). (Lecture III.)
 5.30 p.m. Mr. A. J. B. Wace, "Byzantine Silks."
 At University College, Gower Street, W.C. 5 p.m. Prof. Dr. J. C. Drummond, "Recent Work on Vitamins." (Lecture IV.)
 5.30 p.m. Dr. Thomas Ashby, "The Shores of Latium." (Lecture II.)
 5.30 p.m. Dr. John S. Owens, "Smoke Pollution of the Air and Public Health." (Lecture I.)
 At the University Union Society's Rooms, Malet Street, W.C. 5.30 p.m. Prof. Dr. R. W. Seton-Watson, "The Collapse of Austria-Hungary." (Lecture IV.)
- SATURDAY, NOVEMBER 3.** L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Mr. F. W. Edwards, "A Naturalist's Trip to the Southern Andes."
 Royal Institution, 21, Albemarle Street, W. 3 p.m. Rev. T. E. R. Phillips, "The Planets."
 Sociological Society, Leplay House and Tours Association, at the London Day Training College, Southampton Row, W.C. 10.30 a.m., 2.30 p.m. and 4.45 p.m. Annual Conference.
 United Service Institution, Whitehall, S.W. 3.30 p.m. Lieut.-Commander J. J. C. Irving, "Coronel and the Falklands."

JOURNAL OF THE ROYAL SOCIETY OF ARTS

No. 3963.

VOL LXXVI.

FRIDAY, NOVEMBER 2nd, 1928.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C. (2.)

NOTICE.

OPENING OF THE 175TH SESSION.

The Opening Meeting of the 175th Session will be held at 8.30 p.m. on Wednesday, November 7th, when the Inaugural Address will be delivered by SIR GEORGE SUTTON, Bt., Chairman of the Council. The subject will be "Fifty Years of British Industry."

After the delivery of the Address, the Society's silver medals awarded for papers read last session will be presented.

Tea and coffee will be served in the Library at the end of the proceedings

ROYAL SOCIETY OF ARTS.

REPORT ON THE SOCIETY'S EXAMINATIONS, 1928.

INTRODUCTION.

The year 1928 is a notable landmark in the history of the Society's Examinations, as for the first time the number of entries has reached six figures, the actual total being 100,048.* The curve on page 1204 is an eloquent testimony to the value set by educational authorities and students on these examinations. In 1900 the entries were under 10,000, and they have risen with steady but rapid increases (except during the years of the war) to ten times that figure in twenty-eight years.

* The figures in the diagram on page 1204 give the numbers of papers actually worked at the examinations. The total of these, including 7,871 papers worked at the Group Course Examination for London County Council Junior Commercial and Technical Institutes, and 4,264 papers worked at the Junior School and School Commercial Certificate Examinations, was 95,452.

It has long been the fashion in certain educational circles to decry the value of examinations, and recently the columns of the press have been filled once more by educationalists fighting over again the old, old battle of external *versus* internal examinations. There is a school of idealists who would go so far as to abolish examinations altogether, for, they say, the teacher ought to be able to judge of the merits of his pupils without any such artificial aid. In a perfectly constituted world this would, no doubt, be the case, but teachers, unfortunately, are no more immune from human weaknesses than the rest of the world. A case is on record of a Professor in a Scottish university who was extremely anxious to pass a favourite but incompetent pupil. The external examiner positively refused to agree. After trying all kinds of pleas, the Professor at last exclaimed: "Let her through, let her through, Mr. Mackenzie! The lassie's in love." This story (which is true) may, no doubt, represent the *reductio ad absurdum* of the system of internal examinations, but a considerable experience of examining boards has convinced the writer that teachers are often influenced by a good deal more than their opinions of the intellectual qualities of candidates. The less conscientious are often out to secure as many successes for their own pupils as possible, while the over-conscientious, on the other hand, are sometimes unfair from fear that they may be unduly favouring those whom they have taught themselves. The external examiner is uninfluenced by any of these cross-currents. He can only judge the quality of a candidate from the particular paper before him, and he has no theories as to whether with another paper and in other circumstances the candidate might not have done much better or much worse.

Whatever may be said of the drawbacks of examinations—and that they have drawbacks few will be prepared to deny—it seems clear that they possess some very great advantages in the case of the type of candidates who enter for the Society's examinations. A large number of these are part-time students. Occupied in business or other work during the day, they must exercise considerable self-restraint and will power to follow up a prolonged course of study in the evening. To such as these a good syllabus is an invaluable guide in their reading; the examination gives a definite incentive to their study and a definite goal to aim at, while the hope of a certificate whose value will be known to possible employers, must act as an additional stimulus to systematic work.

EVENING COMMERCIAL EXAMINATIONS.

The Evening Commercial Examinations were held at three periods, March-April, May and July. In March-April the number of entries was 28,389, in May, 43,404, and in July, 15,446. The papers worked were divided among the three Examinations as follows:—

	March-April.	May.	July.	Total.
Advanced Stage ..	2,655	7,108	—	9,763
Intermediate Stage..	8,413	16,611	5,051	30,075
Elementary Stage ..	15,977	17,612	9,890	43,479

In addition to the 83,317 papers worked in the written examinations, 633 candidates presented themselves for the *viva voce* Examinations in Modern Languages.

The subjects of Examination this year were :—

Arithmetic.	Commerce.
English.	Railway Law and Practice.
Book-keeping.	Railway Economics.
Shorthand.	Shipping Law and Practice.
Typewriting.	Law and Practice of Marine Insurance.
Economic Geography.	Stock Exchange Law and Practice.
Economic and Social History.	Advertising and Salesmanship.
Economic Theory.	French.
Précis-writing.	German.
Commercial Law.	Italian.
Company Law.	Spanish.
Accounting.	Russian.
Banking.	Portuguese.
Costing.	Swedish.
Foreign Exchange.	

Arithmetic.—The total number of papers worked in this subject was 11,412, an increase of nearly 1,000 over the corresponding figure for last year. In Stage III there were 435 candidates, of whom 47 obtained first-class certificates, 168 obtained second-class certificates, and 220 failed. While some excellent papers were worked, a large number were nowhere near the standard required for this Stage, the commonest points of weakness being ignorance of mensuration formulæ, errors in logarithmic work, confusion between capital outlay and yearly accounts, and ignorance of banker's discount.

In Stage II there were 2,739 candidates, of whom 737 obtained first-class certificates, 1,077 obtained second-class certificates, and 925 failed. The results, especially in the May examinations, show a distinct improvement as compared with those of last year, and the style was generally good. The examiner finds it necessary to sound a note of warning to candidates and their teachers on the use of logarithms. A good many young students try to use them before they thoroughly understand them, and they often introduce absurd errors; others, again, use them for sums for which they are quite unsuitable. A similar danger is to be found in the use of algebra. For instance, in one question many candidates gave the length of the walk as — 15 miles, and did not seem to know that anything was wrong. A little common sense is not out of place in arithmetic, as elsewhere, and would have saved them from committing this absurdity.

In Stage I, of 8,238 candidates, 970 passed with credit, 4,806 passed, and 2,462 failed. With regard to the mental test, the examiner stresses the need for familiarity with the decimalisation of money, which is too much neglected. The general style of work appears to be steadily improving, and there were comparatively few slovenly papers.

English.—The total number of candidates was 6,882. In Stage III there were 375, of whom 23 obtained first-class certificates, 211 obtained second-class certificates, and 141 failed. The main characteristic of the work was mediocrity, as the small number of first-class certificates showed. A few candidates showed intimate knowledge and appreciation of the prescribed books and a capacity to discuss them in a clear and attractive manner; but far too many betrayed ignorance of the books and inability to grasp and keep to the point of a question.

In Stage II, of 2,132 candidates, 182 obtained first-class certificates, 1,333 obtained second-class certificates, and 617 failed. Some good essays were written, and many candidates had studied the prescribed books with care. Unfortunately a number of candidates whose work in other subjects was good lost marks through very bad spelling. In the case of the worst candidates the spelling was occasionally atrocious.

In Stage I there were 4,375 candidates, of whom 95 passed with credit, 2,671 passed, and 1,609 failed. The varying standards of batches of scripts showed that while in some centres the teaching of English is very good, in others it is deplorable. A good many candidates mis-read the questions or the regulations. One, for instance, wrote three essays and nothing else. In a fair number of cases the answers to the questions on the prescribed books were excellent, but the more general questions on literature produced such statements as "R. L. Stevenson's most important work was the Rocket," and "Sir Walter Scott tried to reach the North Pole but died in the attempt."

Book-keeping.—The total number of papers worked in this subject was 23,862, being an increase of 856 over the figure for 1927. In Stage III there were 3,982 candidates, of whom 285 obtained first-class certificates, 1,730 obtained second-class certificates, and 1,967 failed. The examiners report that in the March examination some papers of great merit were worked, but, as a rule, the questions dealing with income tax and goods on sale or return were very poorly answered.

In Stage II, of 8,443 candidates, 939 obtained first-class certificates, 4,971 obtained second-class certificates, and 2,533 failed. The exercises were generally well worked, but any item at all out of the ordinary caused candidates to get into difficulties.

In Stage I, of 11,437 candidates, 629 passed with credit, 5,820 passed, and 4,988 failed. It is satisfactory to note that there is continued improvement in the general style and neatness in the working of the exercises, but here again, as in Stage II, candidates who were otherwise good were apt to go astray when called upon to deal with anything at all out of the ordinary.

Shorthand.—The total number of candidates in this subject, including those who entered for the L.C.C. Grouped Course and the Society's School and Junior School Commercial Certificates, was 19,055, as compared with 17,201 in 1927. Of these, 69.54 per cent. passed and 30.46 per cent. failed, an increase of 9.21 per cent. in the total percentage of passes, as compared with last year's results. The Examiner is of opinion that there has been an all-round improvement, and that the work of the successful candidates is certainly better than that of recent years.

In Stage III there were 1,502 candidates, of whom 135 passed at 140 words per minute, 547 passed at 120 words per minute, and 820 failed. A certain number of students handicapped themselves by bungling in turning over the pages of their shorthand notes, and in one case no fewer than thirty words were dropped in this way. Though apparently a trivial matter, this is a point to which teachers and students should give some attention. A little practice is all that is wanted to overcome the difficulty.

In Stage II there were 7,511 candidates, of whom 799 passed at 100 words per minute, 3,208 passed at 80 words per minute, and 3,504 failed. Amongst these were four blind students, who all passed at 80 words per minute. Their transcripts were typewritten, and were very neat. This stage produced its usual crop of nonsensical misrenderings: e.g., "diseases and pests" appeared as "desires and

pastures" and "flies and beasts," and "profit bonus" as "private pensions." A number of candidates seem to be under the impression that their shorthand notes are unimportant, and that it is really only the transcript that matters. This is a great mistake. The highest speeds are only likely to be attained if the shorthand outlines are satisfactory.

In Stage I there were 7,115 candidates, of whom 2,869 passed at 60 words per minute, 2,209 passed at 50 words per minute, and 2,037 failed. Papers were worked by 7, blind candidates, who all passed at 60 words per minute.

Economic Geography.—Steady improvement in the teaching of this subject is evident, and the reports on the work in all three stages are most encouraging. Some credit for this is doubtless due to the Examiner, who has always been at pains to write long and helpful reports. These have evidently been read and digested by teachers and students, with the gratifying result that many of the faults which were once general are tending to disappear. The quality of the sketch-maps, for instance, has improved enormously, and, as the Examiner puts it, "argument is displacing catalogues."

In Stage III, of 62 candidates, 4 obtained first-class certificates, 38 obtained second-class certificates, and 20 failed. The quality of the sketch-maps was very satisfactory, and the average standard of the papers was high. Most of the answers were really "geographical," and afforded evidence of sound teaching.

In Stage II, of 323 candidates, 40 obtained first-class certificates, 168 obtained second-class certificates, and 115 failed. The papers worked in May were the best Intermediate set for many years. The excellence of the sketch-maps is again commented on, and the tendency of candidates to use their intelligence in explaining facts.

In Stage I there were 816 candidates, of whom 28 passed with credit, 528 passed, and 260 failed. Generally the papers made it clear that the progress which has been maintained for several years is continuing, but the Examiner has found it necessary to draw attention to one danger which is developing, and that is merely mechanical cram. "Stock" questions were answered by groups of students in amazing identity of language. Apart from this grave defect, the work was satisfactory.

Typewriting.—The total number of candidates in this subject was 9,823, an increase of 981 over the figure for 1927. In Stage III there were 1,099 candidates, of whom 431 obtained first-class certificates, 541 obtained second-class certificates, and 127 failed. The time test was executed with accuracy and speed, and the standard of excellence was much the same as in recent years. In Stage II there were 3,871 candidates; 1,581 obtained first-class certificates, 1,791 obtained second-class certificates, and 499 failed. The tabular statement was, with few exceptions, excellently worked. In Stage I the number of candidates was 4,853, of whom 1,658 passed with credit, 2,378 passed, and 817 failed.

Economic and Social History.—There has been a considerable increase in the number of candidates taking this subject, the total for this year being 268 as compared with 186 in 1927. In Stage III, of 25 candidates, 8 obtained first-class certificates, 15 obtained second-class certificates, and 2 failed. A good general level of intelligent and careful knowledge was shown in the work, and the proportion of failures was very small. In Stage II, of 99 candidates, 14 obtained first-class certificates, 48 obtained second-class certificates, and 37 failed. Some of the work was very good and some very poor, the number of medium papers being

much less than usual. In Stage I there were 144 candidates, of whom 30 passed with credit, 93 passed, and 21 failed. The papers generally reached a good level of merit, and there were few bad failures. The work gave evidence of much careful study and keen interest in the subject, together with plenty of accurate knowledge, firmly gripped and intelligently stated.

Economic Theory.—The total number of candidates was 500. In Stage III there were 217, of whom 27 obtained first-class certificates, 137 obtained second-class certificates, and 53 failed. In the March papers the general level was good, and there were few failures, but in the May scripts there was some very poor work, showing that some of the candidates should have attempted the Intermediate instead of the Advanced Stage. In Stage II, of 283 candidates, 50 obtained first-class certificates, 179 obtained second-class certificates, and 54 failed. Many of these papers showed that the subject had been studied with care, interest and ability.

Précis Writing.—The number of candidates has varied but little for many years and has not increased in this subject as in most of the others. This year there were 132, as compared with 138 in 1927. A good deal is to be said for précis-writing as a training in accurate thinking and condensed expression, but it has gone out of fashion in examinations generally and is no longer considered a "paying" subject to study. A short exercise is often set in ordinary "English" examinations, and this, perhaps, accounts to some extent for the fact that the numbers of candidates taking this subject alone do not increase.

In Stage III there were 33 candidates, of whom 4 obtained first-class certificates, 17 obtained second-class certificates, and 12 failed. To write a good précis of the passage set involved careful exercise of judgment in selecting what it was really important to include and what to omit, but a fair proportion of candidates produced quite good work, and one or two showed distinct talent. In Stage II, of 99 candidates, 14 obtained first-class certificates, 48 obtained second-class certificates, and 39 failed. The average of the work submitted was about on a level with that of previous years.

Commercial Law.—530 candidates presented themselves for examination in this subject. In Stage III the number was 157, of whom 26 obtained first-class certificates, 107 obtained second-class certificates, and 24 failed. The papers on the whole were not up to the usual standard, and there was too much tendency towards irrelevance and to evading the point of the questions. In Stage II, of 373 candidates, 147 obtained first-class certificates, 172 obtained second-class certificates, and 54 failed. The papers here were generally good, a particularly satisfactory feature being that the candidates showed a sound knowledge of the principles of commercial law, and though there was often a lack of knowledge there was seldom a lack of intelligence.

Company Law.—The total number of candidates was 372. In Stage III there were 118, of whom 9 obtained first-class certificates, 71 obtained second-class certificates, and 38 failed. Here, again, questions demanding the application of legal principles were well answered, and welcome improvement was shown in the work on the portion of the paper relating to private companies, which in the past has often been very weak.

In Stage II, of 254 candidates, 109 obtained first-class certificates, 109 obtained second-class certificates, and 36 failed. Most of the answers were characterised by intelligence, but there was too little exact knowledge of the law and practice relating to meetings of companies, powers of chairman, etc.

Accounting.—542 candidates entered for the examination in this subject, which is only held in Stage III. Of these, 40 obtained first-class certificates, 268 obtained second-class certificates, and 234 failed. The question on income tax was generally not well answered, many candidates showing ignorance of the deductions allowed to taxpayers under present regulations. The principles upon which hire-purchase accounts are based seemed also to be unknown to a large number.

Banking.—This subject only attracted 17 candidates, of whom 2 obtained first-class certificates, 10 obtained second-class certificates, and 5 failed. There were no papers of outstanding merit, and, as in former years, the questions requiring a knowledge of bank book-keeping were not well answered.

Costing.—This subject was taken by 99 candidates, of whom 6 obtained first-class certificates, 56 obtained second-class certificates, and 37 failed. The failures would probably be much fewer if candidates would make a greater endeavour to understand the import of the questions before answering them. Ignorance was fairly general as to standard costs and expenses of idle facilities, but many candidates were able to use their records to indicate the savings that should be possible by a concentration of shops.

Foreign Exchange.—Very few candidates are attracted to this subject, the total number being only 17. In Stage III of 7 candidates, 5 obtained first-class certificates and 2 obtained second-class certificates. These results are remarkably good and justify the Examiner's comment that the papers were very encouraging in quality. In Stage II there were 10 candidates, of whom 4 obtained first-class certificates, 5 obtained second-class certificates, and 1 failed.

Commerce.—The total number of candidates was 2,492. In Stage III, of 304 candidates, 14 obtained first-class certificates, 177 obtained second-class certificates, and 113 failed. While the work on the whole was fair there were few scripts of outstanding merit. Candidates at this stage should certainly know the meaning of Bank rate, and the part played by bill brokers ought to be familiar to them. The weakness of some students was evidently due to the fact that they had been studying old and out-of-date text-books.

In Stage II there were 837 candidates, of whom 502 obtained first-class certificates, 276 obtained second-class certificates, and 59 failed. The Examiner reports enthusiastically on the general excellence of the answers which gave indication of very careful preparation on the part of the students. The extraordinarily high percentage of first-classes and the extraordinarily low percentage of failures are certainly most encouraging.

In Stage I, of 1,351 candidates, 682 passed with credit, 573 passed, and 96 failed. Here again there is a satisfactory improvement in the general standard of excellence. In some cases, however, it was evident that the answers had been learnt by heart, for though they were very good in their way they were not answers to questions which had been asked.

Railway Law and Practice.—33 candidates entered for this subject, of whom 8 obtained first-class certificates, 22 obtained second-class certificates, and 3 failed. The principal features of this year's examination was the good general average and the small number of failures. It seems strange, however, that in a country with so many large railway systems as ours, so few candidates should be attracted to this subject.

Railway Economics.—Only 11 candidates entered for this subject; 3 obtained first-class certificates, 6 obtained second-class certificates, and 2 failed. Although the numbers were small the average standard was good.

Shipping Law and Practice.—The total number of candidates was 47 (as compared with 25 in 1927). Of these, 9 obtained first-class certificates, 20 obtained second-class certificates, and 18 failed. A number of these were inadequately prepared and gave answers without any reasons or references to laws or cases.

Stock Exchange Law and Practice.—The hope expressed in last year's Report that in view of the large staffs employed in connexion with the Stock Exchange the number of entries in this subject would increase considerably has not been fulfilled. On the contrary, there has been a falling off from 48 in 1927 to 34 this year. In Stage III there were 14 candidates, all of whom obtained second-class certificates. There were no papers of outstanding merit or demerit. In Stage II, of 20 candidates, 10 obtained first-class certificates, 6 obtained second-class certificates, and 4 failed. The general standard of work was very good, and it is satisfactory to note that the English and spelling (which drew adverse comments from the Examiner last year) were noticeably better than formerly.

Law and Practice of Marine Insurance.—This subject was included in the examinations syllabus for the first time this year, and the number of entrants, 49, may be considered as satisfactory. 7 obtained first-class certificates, 26 obtained second-class certificates, and 11 failed. The general level of knowledge displayed was good, but unfortunately too many papers contained faults of grammar and spelling which should certainly not be committed by candidates at the Advanced Stage.

Advertising and Salesmanship.—70 candidates entered for this subject; 32 obtained first-class certificates, 27 obtained second-class certificates, and 11 failed. The proportion of first-class certificates is very high, but the results would probably have been still better if more candidates had read the questions more carefully and given exactly the answers which were required. Many candidates showed weakness in such matters as Trade Mark Law and the comparative value of newspapers.

French.—The number of candidates taking French continues to increase steadily, having risen from 5,437 in 1927 to 5,726 this year. In Stage III, of 423 candidates, 36 obtained first-class certificates, 230 obtained second-class certificates, and 157 failed. A few excellent essays were submitted, and some candidates showed a very satisfactory knowledge of history and literature. In Stage II there were 1,886 candidates, of whom 234 obtained first-class certificates, 665 obtained second-class certificates, and 987 failed. Some of the work was very good indeed, but a large number of candidates were quite unprepared for an examination of this standard. The Examiner points out that some of the weakest students selected

the commercial part of the paper, but they at once betrayed their ignorance of technicalities and came to grief. On the other hand, the *bonâ fide* commercial candidates, as a rule, acquitted themselves well. In Stage I, of 3,417 candidates, 308 passed with credit, 2,243 passed, and 866 failed. A fairly good general level was maintained, while among the candidates examined in March the Examiner thinks that a good many would have passed in Stage II.

German.—There was a slight drop in the number of candidates in German, the total being 471, as against 583 in 1927. In Stage III there were 52 candidates, of whom 19 obtained first-class certificates, 18 obtained second-class certificates, and 15 failed. The high standard which has for long been a feature of this Stage in German was well maintained. Some spirited translations were given, and the commercial letters were in many cases faultless. In Stage II, of 167 candidates, 34 obtained first-class certificates, 52 obtained second-class certificates, and 81 failed. While a few good papers were worked, there was a general weakness in vocabulary and grammar, and a good many attempted the examination who would have been better advised to enter for the Elementary Stage. In Stage I there were 252 candidates, of whom 23 passed with credit, 132 passed, and 97 failed. In the March papers there was a noticeable improvement in the composition and translation into German, and the answers to the purely grammatical questions were more satisfactory than usual.

Italian.—The total number of candidates was 89. In Stage III there were 18, of whom 9 obtained first-class certificates, 6 obtained second-class certificates, and 3 failed. The work showed that the students had been well prepared; in most cases they had a remarkable command of the language, and their style was good. In Stage II, of 21 candidates, 9 obtained first-class certificates, 11 obtained second-class certificates, and 1 failed. The standard was distinctly higher than that of last year, and the work showed a good knowledge of Italian grammar and vocabulary. In Stage I, of 50 candidates, 9 passed with credit, 34 passed, and 7 failed. Here, again, the work on the whole was very satisfactory, the failures being mainly due to weakness in grammar.

Spanish.—The entries in this subject continue to increase, the total having risen from 802 in 1927 to 935 this year. This development is no doubt largely due to the fact that Spanish is the language of immense areas in South America where markets for British goods are to be found. And here it is interesting to recall that, thanks largely to Sir Philip Magnus, late Chairman of the Council of the Royal Society of Arts, a travelling scholarship in Spanish will be offered next year in connexion with the Society's examinations by the Mitchell City of London Educational Foundation, and it is hoped that this will act as a further incentive to the study of Spanish.

In Stage III, of 108 candidates, 10 obtained first-class certificates, 68 obtained second-class certificates, and 30 failed. The work was generally better than that of last year; many of the essays were excellent and showed that the writers were able to handle the language with facility and correctness. In Stage II, of 292 candidates, 13 obtained first-class certificates, 242 obtained second-class certificates, and 37 failed. Translations from Spanish into English were particularly well done, but though there was certainly improvement in the answers to the grammatical questions, the Examiner finds it necessary to insist on the importance of constant grammatical drill. In Stage I there were 535 candidates, of whom

13 passed with credit, 434 passed, and 88 failed. The papers on the whole reached a very creditable standard and testified to the general excellence of the work done in the schools.

Russian.—The number of candidates, 18, is still very small, and is hardly likely to increase until the prospects of conducting business with Russia begin to improve. No candidates at all entered for Stage III. In Stage II there were 8, of whom 3 obtained first-class certificates, 3 obtained second-class certificates, and 2 failed. In Stage I, of 10 candidates, 2 passed with credit, and 8 passed. In both stages great confusion was caused by the introduction of the new orthography.

Portuguese.—16 candidates entered in Portuguese. In Stage III there were 11, of whom 3 obtained first-class certificates, 6 obtained second-class certificates, and 2 failed. In Stage II, of 5 candidates, 3 obtained first-class certificates, and 2 obtained second-class certificates.

Swedish.—An examination was held in Stage II only of this subject. There were 8 candidates, of whom 2 obtained first-class certificates, 4 obtained second-class certificates, and 2 failed. Most of these candidates showed that they possessed a fair vocabulary, but were weak in grammar.

ORAL EXAMINATIONS.

The results of the Oral Test, which is now compulsory for all candidates in the Advanced Stage of French, German, Spanish, and Italian, were again well up to the average, the figures being much the same as last year. An important part of the Oral Test is the taking down of a passage dictated in the foreign language by the Examiner, and in the past this has been a source of great weakness with many candidates. It is gratifying to be able to state that the examiners now report a very great improvement in this branch of the examination.

ORAL EXAMINATIONS HELD DURING 1928.

Subject.	No. of Examina- tion Centres.	No. of Exami- ners.	No. of Candi- dates. examined.	Passed with Dis- tinction.	Passed.	Failed.
French ..	52	35	455	106	296	53
German ..	13	11	59	14	33	12
Spanish ..	18	16	101	24	59	18
Italian ..	6	5	18	9	9	—
	89	67	633	153	397	83

GROUP CERTIFICATES IN COMMERCIAL SUBJECTS.

The increase, noted in last year's report in the number of candidates entered from Higher Elementary Schools, and also the new Central Day Schools set up under various Education Authorities, has been well maintained. Most of these candidates take a number of subjects qualifying for the Group Certificate in

Elementary Commercial Subjects. To gain this special certificate candidates must pass in Arithmetic, English and two other subjects within three consecutive years, but it is satisfactory to find that many pupils from Day Schools pass in the necessary subjects in one year. In view of the fact that a fairly high standard is maintained in the Elementary Stage (it is by no means a first year's examination), the results at these Schools give evidence of really excellent preparation.

The qualification for Group Certificates is as follows :—

Advanced Stage.—Candidates must pass in the following four subjects in the Advanced Stage in three consecutive years: Book-keeping, Commerce, Economic Theory, and any one of the remaining subjects (other than Shorthand, Typewriting; and Précis-Writing), in which an Examination in the Advanced Stage is held.

Intermediate Stage.—Candidates must pass in the following four subjects, either in the Advanced or Intermediate Stage, in three consecutive years: Arithmetic, Book-keeping, Commerce, and any one of the other subjects in which an Examination in the Intermediate Stage is held. (For the purpose of this Certificate, Shorthand and Typewriting are considered as one subject.)

The thanks of the Council are once more accorded to the Court of the Cloth-workers' Company, who have generously renewed their grant of £40 towards providing medals in all the subjects of examination where the work of candidates attains a sufficiently high standard. There is no doubt that there is very keen competition for these medals, and that they have done much to maintain or raise the level of excellence in the papers worked.

SCHOOL AND JUNIOR SCHOOL CERTIFICATE EXAMINATIONS.

A new series of Examinations was instituted last year, specially designed for candidates from Day Schools.

The subjects of examination are :—

COMPULSORY SUBJECTS: Arithmetic, Book-keeping, Economic Geography, English, History.

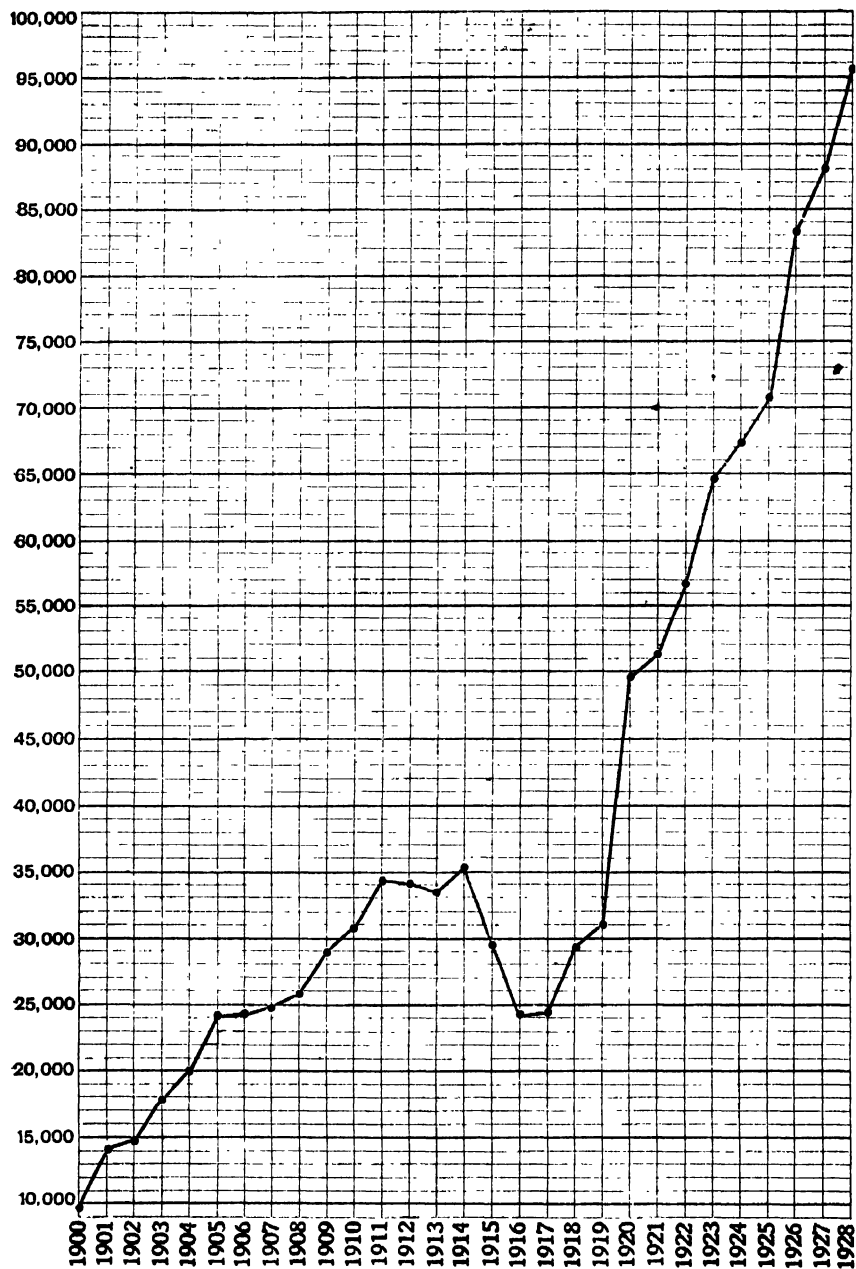
ELECTIVE SUBJECTS: French, German, Spanish, Italian (not more than two foreign languages may be taken), Commerce, Shorthand, Typewriting (School Commercial Certificate only), Mathematics, and Natural Science (Physics, Chemistry, and Botany). Candidates must take not less than two and not more than four of these subjects.

The total number of candidates was 516. Of these 89 entered for the School Commercial Certificate. Twelve obtained a first-class full certificate, and 38 obtained second-class full certificates. For the Junior School Commercial Certificate there were 427 candidates; 81 obtained full first-class certificates, and 208 obtained full second-class certificates. Candidates who failed to obtain full certificates received certificates for the subjects in which they passed.

EXAMINATIONS FOR LONDON COUNTY COUNCIL JUNIOR COMMERCIAL AND JUNIOR TECHNICAL INSTITUTES.

At the request of the Education Committee of the London County Council, the Society undertook last year to hold course examinations for (a) students in L.C.C.

Diagram Showing Numbers of Papers worked in the Royal Society of Arts Examinations, 1900—1928.



DETAILS OF THE 1928 EXAMINATIONS.

SUBJECTS.	STAGE III.—ADVANCED.				STAGE II.—INTERMEDIATE.				STAGE I.—ELEMENTARY.				Total number of Papers worked in all Stages.	
	Papers worked.	1st-class Certi- ficates.	2nd-class Certi- ficates.	Not Passed.	Papers worked.	1st-class Certi- ficates.	2nd-class Certi- ficates.	Not Passed.	Papers worked.	Passed with credit.	Passed.	Not Passed.	1928	1927
Arithmetic	435	47	168	220	2,739	737	1,077	925	8,238	970	4,806	2,462	11,412	10,533
English	375	23	211	141	2,132	182	1,333	617	4,375	95	2,671	1,609	6,882	6,845
Book-keeping	3,982	285	1,730	1,967	8,443	939	4,971	2,533	11,437	629	5,820	4,988	23,882	23,006
Economic Geography	62	4	38	20	323	40	168	115	816	28	528	260	1,201	1,106
Shorthand	1,455	123	810	522	8,205	1,800	3,502	2,903	8,001	3,216	2,882	1,903	17,661	16,128
Typewriting	1,099	431	541	127	3,871	1,381	1,791	499	4,853	1,658	2,378	817	9,823	8,842
Economic and Social History	25	8	15	2	99	14	48	37	144	30	93	21	268	186
Economic Theory	217	27	137	53	283	50	179	54	—	—	—	—	500	615
Précis-writing	33	4	17	12	99	12	48	39	—	—	—	—	132	138
Commercial Law	157	26	107	24	373	147	172	54	—	—	—	—	530	517
Company Law	118	9	71	38	254	109	109	36	—	—	—	—	372	344
Accounting	542	40	268	234	—	—	—	—	—	—	—	—	542	516
Banking	17	2	10	5	—	—	—	—	—	—	—	—	17	16
Costing	99	6	56	37	—	—	—	—	—	—	—	—	99	117
Foreign Exchange	7	5	2	—	10	4	5	1	—	—	—	—	17	32
Commerce	304	14	177	113	837	502	276	59	1,351	682	573	96	2,492	2,161
Railway Law and Practice	33	8	22	3	—	—	—	—	—	—	—	—	33	55
Railway Economics	11	3	6	2	—	—	—	—	—	—	—	—	11	7
Shipping Law and Practice	47	9	20	18	—	—	—	—	—	—	—	—	47	25
Stock Exchange Law & Practice	14	—	14	—	20	10	6	4	—	—	—	—	34	48
Law and Practice of Marine Insurance	49	7	26	16	—	—	—	—	—	—	—	—	49	—
Advertising and Salesmanship	70	32	27	11	—	—	—	—	—	—	—	—	70	62
French	423	36	230	157	1,866	234	665	987	3,417	308	2,243	866	5,726	5,437
German	52	19	18	15	167	34	52	81	252	23	132	97	471	583
Italian	18	9	6	3	21	9	11	1	50	9	34	7	89	92
Spanish	108	10	68	30	292	13	242	37	535	13	434	88	935	802
Russian	—	—	—	—	8	3	3	2	10	2	8	—	18	17
Portuguese	11	3	6	2	5	3	2	—	—	—	—	—	16	13
Swedish	—	—	—	—	8	2	4	2	—	—	—	—	8	—
Totals, 1928	9,763	1,190	4,801	3,772	30,075	6,425	14,664	8,986	43,479	7,663	22,602	13,214	83,317	—
„ 1927	9,272	1,367	4,289	3,616	28,733	5,618	14,514	8,601	40,137	6,054	20,391	13,692	—	78,142

In addition to the figures given above, 7,871 papers in the Elementary Stage were worked in May at the Group Course Examination for London County Council Junior Commercial and Technical Institutes, and 4,264 papers were worked at the Junior School and School Commercial Certificate Examinations held in July. The grand total of papers worked in 1928 is, therefore, 95,462.

Junior Commercial Schools, and (b) students in L.C.C. Junior Technical Schools.

The total number of entries from both classes of Schools was 2,784. There were 1,682 candidates from the Junior Commercial Schools, of whom 989 obtained group certificates; and 869 from the Junior Technical Schools, of whom 519 obtained group certificates.

NOTES ON BOOKS.

ELECTRICAL TRANSMISSION AND DISTRIBUTION. To be completed in about thirty parts. Edited by R. O. Kapp, B.Sc., London. Sir Isaac Pitman and Sons, Ltd. Each part 1s. net.

Readers of technical literature will welcome, as the editor of the subject under review, Mr. R. O. Kapp, a son of the late Dr. Gisbert Kapp, well known as the author of numerous books and papers on electro-technical matters.

In a publishers' note it is stated that the Electricity Commissioners' schemes for the transmission and distribution of electrical energy, which are now being built up, will have the effect of diverting attention to these branches and thus create a demand for reliable information thereon. The complete work will be issued in thirty weekly parts.

Part I, dated October 20th, 1928, points out that, whilst generating station economics are worked out to minute figures of thermal efficiency, on the transmission side there may be differences of 30 per cent. or more on the capital cost between two alternative lay-outs, and that literature discussing such lay-outs is not easy to find.

The work is intended to explain the fundamental principles of the subject, and to deal with the construction of the varied types of transmission lines that may be called for.

Consideration is given to the carrying capacity of the line as determining whether short or long span construction would prove the better proposition, the trend of modern design being towards longer spans with exceptional lengths to cross rivers, etc., ranging up to 1,250 feet.

The selection of conductors is also dealt with on the bases of price, weight, strength and resistance to atmospheric destruction; hard-drawn copper and steel-cored aluminium are the materials frequently adopted; there is also copper-clad steel.

Porcelain is given as the material most commonly used for insulation, whilst other types are referred to.

The question of protection in order to avoid trouble caused by birds, thunderstorms and tempests, affords the author scope for easily-digested information; but the important question of "sag" brings to the reader a set of formulæ on which he might, with advantage, work out some theoretical examples, in order to master the subject when called on to do so in actual practice.

Coronal spacing of conductors is covered by reference to other handbooks, which in a work of this kind is a little disappointing; spacing to avoid contact is more fully discussed.

The edition is well printed, and the first part has 41 illustrations on its 64 pages; also numerous tables, curves and formulæ.

The list of names of contributors to the work ensures to the reader a good supply of useful information on some twenty-five aspects of the subject.

C.A.B.

AN HISTORICAL CATALOGUE OF ENGRAVINGS, DRAWINGS AND PAINTINGS IN THE BANK OF ENGLAND. London: Printed by S. B. Chamberlain.

This interesting catalogue has been privately printed for the Governor and Company of the Bank of England. Mr. Montagu Norman tells us in the Preface that a full history of the bank is to follow later.

The catalogue is illustrated by twenty-nine plates and a coloured frontispiece. This picture shows the Bank in 1816, and as Dance's Mansion House can just be seen, on the left one can get from it a good idea of what the famous centre of affairs looked like just over a century ago. Plates V and VI also suggest a very different prospect from the one that greets thousands of city men every morning in the twentieth century.

Observe in Plate V that the Bank is surrounded with Lottery Offices. The State Lottery adjoins the Church of St. Christopher-le-Stocks, while Mr. Richardson's firm, "Good Lucks," stands opposite Irving's Fruit Lozenge warehouse. An attempt is being made at present to legalise lotteries once more; it seems absurd that they should have to be elaborately disguised as "competitions."

In contrast to the somewhat cold aquatints of interiors of the Bank is Rowlandson's amusing illustration of "Sir Robert Taylor's Rotunda when used as the Stock Exchange." (Plate XV). The drawing is not in very good perspective, but probably not more inaccurate than Thomas Malton's severe water-colour of the same Rotunda reproduced as Plate XIV. Pugin and Rowlandson together did an excellent and lively picture of the Pay Hall, 1808, Plate XIX, the detail of which appears to be as trustworthy as the atmosphere is vivid.

C. Turner's mezzotint of Sir John Soane, after Lawrence, is a fine portrait of a remarkable personality. Soane's small mouth, wide nostrils and heavy eyelids, his faint smile and the slight inclination of his head, are perfectly indicative of the temperamental character that he possessed.

P.B.

MEETINGS OF OTHER SOCIETIES
DURING THE ENSUING WEEK.

MONDAY, NOVEMBER 5.—Architects, Royal Institute of British, 9, Conduit Street, W. 8 p.m. Inaugural Meeting. President's Address.
Automobile Engineers, Institution of, at the Merchant Venturers' Technical College, Bristol. 6.45 p.m.
Dr. E. C. Wadlow, "The Comparative Merits of Road and Dynamometer Testing for Motor Vehicles."
Chemical Industry, Society of, at Burlington House, W. 8 p.m. Mr. J. Arthur Reayell, "The Manufacture of Red Oxide by the Neill Process."
Electrical Engineers, Institution of, at the University of Liverpool. 7 p.m. Mr. W. T. Townend, "Some Considerations of the Economics of Electric Power Production."
Engineers, Society of, at Burlington House, W. 6 p.m. Mr. C. R. Enock, "The Future of Engineering in the Light of Modern Economic Industrial and Political Conditions."
Farmer's Club, at the Hotel Metropole, Whitehall Place, S.W. 4 p.m. Mr. J. R. Bond, "The Development of Agricultural Machinery to suit the Changes in Agricultural Conditions."
Geographical Society, at the Æolian Hall, New Bond Street, W. 8.30 p.m.
Royal Institution, 21, Albemarle Street, W. 5 p.m. General Meeting.
University of London, at the Institute of Historical Research, Malet Street, W.C. 5.30 p.m. Prof. Dr. R. W. Seton-Watson, "Ruthenia."
At King's College, Strand, W.C. 5.30 p.m. Right

Rev. Bishop C. Gore, "Dogma in the Early Church."
At the London School of Economics, Houghton Street, W.C. 5 p.m. Don S. de Madariaga, "Disarmament." (Lecture I).
At University College, Gower Street, W.C. 5 p.m. Prof. E. B. Verney, "Urinary Secretion." (Lecture IV).

TUESDAY, NOVEMBER 6.—Automobile Engineers, Institution of, at the Royal Society of Arts, Adelphi, W.C. 7.45 p.m. Mr. L. H. Pomeroy, "Modern Problems in Engine Lubrication."
British Academy, at the Civil Service Commission Buildings, Burlington Gardens, W. 5 p.m. Prof. Otto Jespersen "Monosyllabism in English."
Civil Engineers, Institution of, Great George Street, S.W. 6 p.m. Opening Meeting. Sir Freddie H. Henderson, Presidential Address.
Colonial Institute, at the Hotel Victoria, S.W. 8.30 p.m. Dr. M. J. Rendall, "Youth and the Empire."
Illuminating Engineering Society, at 15, Savoy Street, Strand, W.C. Opening Meeting. Address by Mr. C. C. Paterson on the International Illumination Congress in the United States. Reports by Committees on Progress in Gas and Electric Lighting.
Industrial Transport Association, at the Old Ship Restaurant, 45, Charing Cross, S.W. 6.30 p.m. Mr. G. C. Rich, "Transport and Export Departmental Co-ordination."
Metals, Institute of, at Armstrong College, Newcastle-on-Tyne. 7.30 p.m. Prof. C. H. Desch, "Deformation of Metals."
At the Engineers' Club, Birmingham. 7 p.m. Mr. F. W. Spencer, "Drop Forging and Machine Forging."

North-East Coast Institution of Engineers and Ship-builders, at Cleveland Institution, Middlesbrough, 7.30 p.m. Mr. W. G. Richards, Chairman's Address.

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Prof. H. L. Callendar, "The Change of State from Liquid to Vapour." (Lecture II).

University of London, at King's College, Strand, W.C. 5.30 p.m. Prof. Albert Cock, "Baron von Hügel." 5.30 p.m. Sir Bernard Pares, "Contemporary Russia." (Lecture V).

At Westfield College, Hampstead, N.W. 5.15 p.m. Sir Charles Grant Robertson, "The Map of Europe." (Lecture I).

WEDNESDAY, NOVEMBER 7. Analysts, Society of Public, at Burlington House W. 8 p.m. (1) Mr. Julius Grant, "Improved Method for the Determination of Small Quantities of Antimony in the Form of Stibine." (2) Mr. H. R. Ambler, "Analysis of Small Samples of Gas." (3) Mr. E. Lester Smith, "Determination of Unsapoxidisable Matter in Oils and Fats." (4) Mr. Paul Arup, "Composition of Irish Butter." (5) Dr. H. B. Dunncliff, "Volumetric Determination of Mercury."

Electrical Engineers, Institution of (Wireless Section), Savoy Place, W.C. 6 p.m. Commdr. J. A. Slee, Chairman's Address.

Geological Society, Burlington House, W. 5.30 p.m. Heating and Ventilating Engineers, Institution of, at Caxton Hall, Westminster, S.W. 7 p.m. Mr. G. A. Cottell, "Heating and Domestic Installations—the Insurance Point of View."

North-East Coast Institution of Engineers and Ship-builders (Graduate Section), at Bolbec Hall, Newcastle-upon-Tyne. 7.15 p.m. Mr. Eric Hinchliffe, Chairman's Address.

Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Dr. Thomas F. Cotton, "Diseases of the Heart and Blood Vessels in relation to Industrial Occupations."

University of London, at King's College, Strand, W.C. 5.30 p.m. Dr. F. A. P. Aveling, "The Indebtedness of Industry to Pure Science." (Lecture IV, "The Human Factor.")

5.30 p.m. M. Leon Pierre Quint, "Marcel Proust: La Vie l'Homme." (In French). (Lecture I).

At the London School of Economics, Houghton Street, W.C. 6 p.m. Mr. F. Hutchinson, "Measuring Output in Office Practice."

At the School of Oriental Studies, Finsbury Circus, E.C. 5.30 p.m. Prof. A. Meillet, "Les Origines du Vocabulaire Européen." (Lecture I). (In French). At University College, Gower Street, W.C. 5.30 p.m. Prof. Dr. J. G. Robertson, "Swedish Romanticism." (Lecture I).

5.30 p.m. Major Cyril Davenport, "Book-binding in Germany."

At the University Union Society's Rooms, Malet Street, W.C. 5.30 p.m. Dr. Julian Krzyzanowski, "Renaissance Poland." (Lecture VI).

THURSDAY, NOVEMBER 8. Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 6.30 p.m. Wing Commr. T. R. Cave-Browne-Cave, "Maclurey Installation of R.101."

Antiquaries, Society of, Burlington House, W. 8.30 p.m. Electrical Engineers, Institution of, Savoy Place, W.C. 6 p.m. Mr. W. B. Woodhouse, "Overhead Electric Lines."

At University College, Dundee. 7.30 p.m. Mr. J. S. Lilly, "Notes on Installation and Maintenance Risks."

Historical Society, 22, Russell Square, W.C. 5 p.m. Miss A. M. Evans, "The Imprisonment of Lord Danby in the Tower (1679-1685)."

L.C.C. The Geoffrey Museum, Kingsland Road, E.2. 7.30 p.m. Mr. Fred Roc, "The Work of Tudor Craftsmen."

Metals, Institute of, at the Royal School of Mines, South Kensington, S.W. 7.30 p.m. Prof. W. E. Dalby, "The Plastic Contour."

Oil and Colour Chemists' Association, at 30, Russell Square, W.C. 7.30 p.m. Mr. A. T. Parsons, "Radium with special reference to Luminous Paints."

Optical Society, at the Imperial College of Science and Technology, South Kensington, S.W. 7.30 p.m.

Refrigeration, British Association of, at the Institution of Mechanical Engineers, Storey's Gate, S.W. 5.30 p.m.

Dr. L. H. Lampitt and Mr. P. Bilham, "The Keeping and Distribution of Food (chiefly Dairy Products), with special reference to the Use of a Eutetic as a Refrigerant."

Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Capt. G. Pitt-Rivers, "Culture-Clash in a Maori Village."

University of London, at Bedford College for Women, Regent's Park, N.W. 4.15 p.m. Prof. Eccles, "Pierre Corneille." (In French). (Lecture VI). 5.15 p.m. Prof. Dr. Robertson, "Travel as a Factor in Human Life." (Lecture III).

At King's College, Strand, W.C. 5 p.m. Dr. W. Robson, "Protein Metabolism." (Lecture II).

5.30 p.m. Prof. A. J. Grant, "Montesquieu."

5.30 p.m. Mr. J. Isaacs, "Bunyan as a Literary Artist." (Lecture I).

5.30 p.m. Mr. Ifor L. Evans, "Bessarabia and the Bucovina (to 1914)."

5.30 p.m. M. A. F. Meyendorff, "Social Legislation of the Soviet Government." (Lecture III).

At the School of Oriental Studies, Finsbury Circus, E.C. 5.30 p.m. Prof. A. Meillet, "Les Origines du Vocabulaire Européen." (Lecture II). (In French). At University College, Gower Street, W.C. 3 p.m. Dr. Camillo Pellizzi, "La Lirica del Paradiso." (Lecture I).

1 p.m. Dr. D. H. Smith, "Aspects of Fossil Botany." (Lecture IV).

5.15 p.m. Prof. J. E. G. de Montmorcov, "The Barbarian Codes as illustrating Social Life in Central and South-Western Europe from 450-750 A.D." (Lecture II).

At the University Union Society's Rooms, Malet Street, W.C. 5.30 p.m. Prince D. Sovatopolk Mirsky, "Tolstoy." (Lecture V).

Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Mr. Eric Maclagan, "Three Early Sculptors of the Renaissance (Iacopo dalla Quercia, Ghiberti, Luca della Robbia)."

FRIDAY, NOVEMBER 9. Astronomical Society, Burlington House, W. 5 p.m.

Faraday Society, at the Royal Institution, 21, Albemarle Street, W. 3.30 p.m. Sir Oliver Lodge, F.R.S., "Some Debatable Problems in Physics." (Spurs Memorial Lecture).

Mechanical Engineers, Institution of, Storey's Gate, S.W. 7 p.m.

Metals, Institution of, at the University of Sheffield. 7.30 p.m. Prof. F. C. Thompson, "Flow in Metal Shaping Processes."

Oil and Colour Chemists' Association, Milton Hall, Deansgate, Manchester. 7.30 p.m. Mr. B. Campbell, "Nitrocellulose Finishes."

Physical Society, at the Imperial College of Science and Technology, South Kensington, S.W. 5 p.m.

University of London, at King's College, Strand, W.C. 5.30 p.m. M. Leon Pierre Quint, "Marcel Proust: La Vie l'Homme." (In French). (Lecture II).

At the School of Oriental Studies, Finsbury Circus, E.C. 5.30 p.m. Prof. A. Meillet, "Les Origines du Vocabulaire Européen." (Lecture III). (In French). At University College, Gower Street, W.C. 5 p.m. Prof. Dr. J. C. Drummond, "Recent Work on Vitamins." (Lecture V).

5.0 p.m. Dr. Thomas Ashby, "The Shores of Latium." (Lecture II).

5.30 p.m. Dr. John S. Owens, "Smoke Pollution of the Air and Public Health." (Lecture II).

5.30 p.m. Mr. W. L. Cook, "The British Coal Industry."

At the University Union Society's Rooms, Malet Street, W.C. 5.30 p.m. Prof. Dr. R. W. Seton-Watson, "The Collapse of Austria-Hungary." (Lecture V).

SATURDAY, NOVEMBER 10. L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Mr. John E. S. Dallas, "Swiss Scenes and Flowers."

Mechanical Engineers, Institution of, at Glasgow. Discussion on "Steel Castings," by Dr. A. McCance and Mr. J. Jefferson.

Royal Institution, 21, Albemarle Street, W. 3 p.m. Rev. T. E. R. Phillips, "The Planets." (Lecture II).

United Service Museum, Whitehall, S.W. 3.30 p.m. Commander the Hon. S. M. A. J. Hay, "Modern Ships of the Royal Navy."

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FRIDAY, NOVEMBER 9th, 1928.

All communications for the Society should be addressed to the Secretary, John Street, Adelphi, W.C.(2.)

NOTICE.

NEXT WEEK.

MONDAY, NOVEMBER 12th, at 8 p.m. (Cantor Lecture). FRANKLIN KIDD, D.Sc., Low Temperature Research Station, Cambridge, "Biology and Refrigeration." (Lecture I).

WEDNESDAY, NOVEMBER 14th, at 8 p.m. (Ordinary Meeting). OMAR RAMSDEN, R.M.S., "English Silver and its Future." THE RIGHT HON. THE EARL OF CRAWFORD AND BALCARRES, K.T., P.C., LL.D., F.R.S., P.S.A., will preside.

NOTES ON BOOKS.

MODERN ASTRONOMY : ITS RISE AND PROGRESS. By Hector Macpherson. Oxford University Press. London : Humphrey Milford. 6s. net.

THE FUNDAMENTALS OF ASTRONOMY. By S. A. Mitchell, and C. G. Abbot. London : Chapman & Hall, Ltd. 15s. net.

STARS AND ATOMS. By A. S. Eddington. Oxford : At the Clarendon Press. 7s. 6d. net.

Mr. Macpherson's book on the rise and progress of our modern astronomy is in all respects a pleasant book to handle and to read. The crown octavo size of the page, the rather thin paper, and the good printing conduce to portability and legibility, so that a general reader who wishes to obtain a somewhat intimate knowledge of the old and new in astronomy may even carry the book in his pocket for occasional reading. By a lucid, carefully exact and concise style, Dr. Macpherson contrives to include much in a small book, and his general sense of balance and fitness—combined with the historical sense, or instinct, for grasping the real significance of sequences—has enabled him to produce a really good first book in astronomy, suited for young or old, and worthy to run through many editions.

Eruptive vortice actions in fluids are illustrated by solar photographs, and it is interesting to notice how well these whirlpool appearances accord with Faye's theory that the fixed stars are fluid masses, *i.e.*, liquid and gaseous, approximately concentric in order of density. For a good general account of Faye's long-neglected views, reference may be made to a sequence of articles on "The New Astronomy," by Langley, in the *Century Magazine* for 1884, pp. 724-726.

Many of the illustrations in Dr. Macpherson's volume are portraits of pioneer workers; the portrait being a basis upon which we find a summary of the astronomical labours of the individual.

"The Fundamentals of Astronomy," by Mitchell and Abbot, both American astronomers of eminence, is a much larger text book than that of Macpherson, and it may serve well as a second text-book for a student who has read the first work under notice. It deals with many subjects of every-day importance. Thus, on pp. 72 and 73 we have an abstract of the various proposals for reforming the calendar, then a paragraph on the standard or zone times which have been adopted as a consequence of widespread use of telegraphic or like methods. Next comes a short note on "Daylight Saving" by an altered clock, but perhaps the most important matter in relation to recent devices for avoiding troubles incidental to time-keeping is the chart on p. 74, showing the "International Date Line;" the thoughtful and instructive explanatory text which follows being well worth reading as a mental exercise, also as a lesson in practical utility as bearing on a default in theoretical perfection.

Professor Eddington's book "Stars and Atoms" is not a general text-book, either of astronomy or atomics, but it is a brilliant, well-illustrated and attractive treatise on fluidity, temperature and condition in the fixed stars, our sun being that of which we have most definite knowledge. This book is one that may be confidently recommended to our supposed student as a third reading book; not so much from the standpoint of definitely established facts, as by serving as a mental hormone or stimulant, giving light and speculative views. In the preface we are told that the book is "discursive rather than systematic;" hence we must criticise details according to the spirit of the preface, and accept a quaint and rather informal style. It is difficult to imagine any reasonable objection to Eddington's association of stars and atoms--the gigantic and the extremely minute--when problems in physical science are considered, but as he seems to regard the answering of unmade objections as a part of his rhetoric, it may be allowable to refer to the first page of the text (p. 9) and make a few notes on the dialectics adopted in answering unformulated or non-existent objections.

Denuded of superfluous words, the meaning of the proposition on p. 9 appears to be:--Man being nearly medial as to mass or weight between star and atom, can therefore survey the grandest or the most minute. The idea that intelligence is a function of mass is perhaps more severely and effectually satirised by Voltaire in his *Micromégas*, than by Swift in partly similar writings; and to assume that we can approximately estimate the average mass of either stars or atoms, if regarded broadly or generally, is perhaps going too far in vague and speculative paths.

Moreover, the mathematical position brought forward in support appears to us somewhat unsatisfactory and out of conformity with the author's teaching in another place. On p. 9 it appears to be assumed that *ten to the power of twenty-seven*, and *ten to the power of twenty-eight*, nearly correspond in the approximate, or rough, aspect under argument; but the careful reader will regard those expressions which we translate into italicised words, as differing very considerably, the latter **being** ten times the former. Thus, if the mathematical aspect on p. 9 holds good,

our two italicised data must be nearly equal, but they are to each other as one to ten. Turning to page 24 we see a number terminating with a long sequence of noughts, ranged as plain figures across the page, but in this case there is an emphatic caution against making an error as to the number of noughts.

On page 100 we read of "0.03 grammes of energy," and, apart from any question as to expediency in using a plural noun to indicate less than two units, many may fail to grasp the notion of energy expressed in grammes. The view that energy, as light for example, possesses weight is by no means new. Babbage, who was a successor to Newton in the Lucasian chair of mathematics at Cambridge, has speculated at some length on the mutual relations of energy and mass or weight. On p. 180 of the 2nd or 1838 edition of his "Ninth" Bridgewater Treatise, Babbage considers and develops Mosotti's theory that matter consists of polarised centres of force, and Babbage extends his study of the subject until he explains how matter may "be said to radiate:" the lighter particles flying off at right angles. Again, Babbage speculates, but in the concluding paragraph of p. 184 (edition already mentioned, 1838, Murray) we arrive at a concept as regards liquid or gaseous fluidity of atomic centres, or at levels in atomic structures, when matter may have arisen from energetic particles; these speculations being remarkable links between Boscovich (1759), Crookes, at the British Association meeting of 1879 and subsequently, also Eddington, who has conjectured as to a gaseous form of matter many times denser than platinum. He also, on p. 98 of the work under notice, writes at some length on the view that light possesses actual weight, and he seems to suggest the conceivableness of buying light by the pound, also of recognising a one-pound load in the containing vessel.

Our imaginary student, after having experienced how Eddington leads him on mental journeys between star and atom in the lighter vein, may turn to a work published by the Oxford University Press in 1850: the second edition of Dr. Daubeny's Introduction to the Atomic Theory, a volume of 502 pages, which stands high as a summary of atomic theories from Anaxagoras and Empedocles to Dalton and Joule. During the past three decades the trend of thought has bent towards that radiant constituent of matter which Babbage predicted on theoretical grounds, and which Crookes discovered experimentally; these particles being termed "electrons" by Dr. Johnstone Stoney, and during the past twenty years Dr. Stoney's word "electron" has been a central position in many widely varying theories as to the ultimate nature of matter and of such radiant energy as we exemplify by "light"; taking the term in its extreme sense, or apart from any limitation by the visible spectrum. Recently, owing to the speculations of De Broglie, Schrödinger and, chiefly, C. G. Darwin, we appear to be on the threshold of what has been termed a "brilliant synthesis" of the two classical views as to the nature of light. If to the carrier-wave view we add the emissive-ray concept of ether as put forth by Worster, we are in a position to cast off the mental aid of an interstellar medium and to fit "by hypothesis," the carrier-wave and the emissive ether-ray with any desired outfit of energetic particles or conditions. Thus the scope for pragmatic (fitting or working) speculation seems unbounded: nevertheless, one who has carefully read Dr. Sidney Hook's recent work on "The Metaphysics of Pragmatism:" may pause and hesitate.

PICTURES AND HOW TO CLEAN THEM. By T. R. Beaufort. London: Bodley Head. 7s. 6d.

As Mr. Dolman, who writes the preface, says of this book: it is a striking example of *multum in parvo*. The author's knowledge is impressively wide, and his method

of communicating it is as leisurely and amusing as it is careful. He speaks of cleaning in general and in particular. To clean Cuyp, for instance, is easy, owing to his hard glazing. Claude presents difficulties, because he had a way of "scrubbling a film of colour over the whole picture" in a very "refined" manner. Veronese, disconcertingly for a cleaner, painted in blue draperies in water-colour. Reynolds also is hard to deal with, as he was given to experimenting and used copal varnish and bitumen. "Haydon is said to have rushed at his canvases with brushes brimming with asphaltum"; and Turner sometimes used the same medium. "When Turner was asked what he mixed with his colours he answered 'brains.' In cleaning pictures it is necessary to use brains—and plenty."

The cleaning of water-colours is particularly difficult, "so much so that to those about to undertake it one might offer *Punch's* advice to those about to marry." For those who reject this advice Mr. Beaufort has detailed instructions.

There follow chapters on colours, acids and alkalis; then we come to symbolism in art, knowledge of which helps to identify figures in mutilated pictures, stained glass, etc. In parenthesis, it appears that during the first half of the eighteenth century in London there was a vogue for symbolic signs to indicate the callings of householders. "Signs were at length deemed a public nuisance, and the law in 1764 caused their removal, and the houses consequently began to be numbered, New Burlington Street being the first to be so distinguished."

The invention of ink is attributed by the Chinese to one Tien-Tchen, who lived about 4,600 years ago. His ink was a kind of solution of lacquer, which the ink-makers of Kiang-Si improved on twenty-three centuries later with a mixture of lacquer, wood and size. Chinese (or Indian) ink is easier to deal with in cleaning than ivory-black, which is, chemically speaking, animal charcoal, and discolours readily.

Chapter XVII, on picture fakers, is most interesting. Mr. Beaufort tells us how these ingenious gentlemen work, from Imhoff of Nuremburg, who with his apprentices turned out scores of sham Dürers, to Abrier, who flooded the market with pseudo-Greuze under the Second Empire.

It is surprising to learn that pastels can be cleaned at all: . . . "a difficult operation, but by no means impossible." Having told us about this, Mr. Beaufort concludes his remarkable little book with a chapter on old pottery, which we read to the end, as we do the others.

THE STORY OF ARCHITECTURE IN ENGLAND. PART I.—FROM ROMAN TIMES TO THE REFORMATION. By W. H. Godfrey. London: B. T. Batsford, Ltd. 6s. 6d. net.

At the beginning of his introduction Mr. Godfrey has a very encouraging sentence. He writes: "Man, the arch-imitator, has wanted to play a little at Nature's supreme game and to become not an artificer only, but an artist." That he is not here saying more than he means is made clear in the next paragraph. "We have studied natural beauty and natural science with so much enthusiasm that we sometimes forget one big fact, and that is, that man lives in a world of his own. . . Following the laws of his own being man uses Nature for human purposes. . . he moulds Nature to the proportions and the scale which fit in with his human conception of what is harmonious. . ." By "we" Mr. Godfrey means modern man; but medieval man, who studied neither natural beauty nor natural science with any enthusiasm, did not for that appreciate the point in question, while the Greeks, who *did* study these things, were careful not to lose sight of the principle that we call humanism.

The humanism of architecture has once and for all been enunciated by Geoffrey Scott in an admirable essay. Truly humanistic building went down with the Roman Empire and only revived with the Renaissance; but if the Gothic architecture with which Mr. Godfrey deals was not humanistic, it was certainly very human, a monument to the vague though passionate aspirations of a humanity divided against itself and unreconciled to its real nature.

Mr. Godfrey's book is richly illustrated with drawings by many artists. The history begins with relics of the Roman occupation; there is no mention of Stonehenge, which is rather a pity: it is as much "architecture in England" as the Saxon crosses at Ruthwell and Bewcastle. A photograph is given of the little Saxon church at Bradford-on-Avon, with its singularly good proportions.

The early Norman church at Kilpeck is similar in design; and in this respect, how much sounder it is than the elaborate Holy Trinity, Blythburgh, built towards the end of the Gothic period, for which Mr. Godfrey has high praise. The more compact churches of earlier times are less like some animal lying down than is the lengthened type with its rib-like buttresses.

We get a reproduction of a charming drawing of the Keep at Rochester, which is being visited by a gentleman in a top hat who is causing a commotion among the sea-gulls. This picture gives a very good idea of the immense thickness of the walls of a keep. Conway, Fig. 49, is the castle of the dreams of childhood.

Chapter X is called "Civil and Domestic Buildings of the Middle Ages." Luckily, England is still dotted with cottages dating from the sixteenth and seventeenth centuries; pre-Reformation ones are rare. The oldest building in the Kentish village where I live is the same sort as Fig. 127; it is inhabited by very poor people, who naturally cannot do much towards helping to preserve it in a good condition, as they have their work cut out to make both ends meet.

Mr. Godfrey's book is well written, and produced by Messrs. Batsford with their usual care. P.B.

THE LIBRARY.

The following books have been presented to the Library since the last announcement:—

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CONTRIBUTIONS TO THE READING ROOM.

The Council acknowledge, with thanks to the Proprietors, the receipt of the following Transactions of Societies and other Periodicals :—

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| African Society, Journal. | Imperial Arts League, Journal. |
| American Academy of Arts and Sciences, Proceedings. | Imperial Institute, Bulletin. |
| American Chemical Society, Journal. | India, Geological Survey, Memoirs and Palæontologia Indica. |
| American Institute of Electrical Engineers, Transactions. | Indian Meteorological Department, Monthly Weather Review. |
| American Leather Chemists' Association, Journal. | Institute of Bankers, Journal. |
| American Philosophical Society, Proceedings and Transactions. | Institute of Brewing, Journal. |
| Architectural Association, Journal. | Institute of British Carriage and Automobile Manufacturers, Journal. |
| Auctioneers' and Estate Agents' Institute, Journal. | Institute of Chemistry, Journal and Proceedings. |
| Australasian Association for the Advancement of Science, Report. | Institute of Metals, Journal. |
| Bath and West of England Society, Journal. | Institute of Wireless Technology, Journal. |
| British Cold Storage and Ice Association, Proceedings. | Institution of Automobile Engineers, Proceedings. |
| British Dental Association, Journal. | Institution of Civil Engineers, Minutes of Proceedings. |
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| Central Chamber of Agriculture, Journal. | Institution of Gas Engineers, Transactions. |
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| Commonwealth Institute of Science and Industry, Bulletin. | Institution of Petroleum Technologists, Journal. |
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| Geneva, Société des Arts, La Revue Polytechnique. | Junior Institution of Engineers, Record of Transactions. |
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- JOURNALS.
- Weekly.*
- Amateur Photographer.
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Cabinet Maker.
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 Paper Trade Review.
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Fortnightly.

British Industries.
 Dyer and Calico Printer.

Jeweller and Metalworker.
 Perak Government Gazette.
 Revue du Travail.
 Revue Générale des Sciences.
 West Indian Committee Circular.

Monthly.

Analyst.
 Architecture.
 Automobile Engineer.
 Brewers' Journal.
 British Builder.
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 Journal of the Department of Agriculture (Pretoria).
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 Master Builder.
 Meteorological Magazine.
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 Mining Electrical Engineer.
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Mysore Economic Journal.
 Norwegian Trade Review.
 Oil Engineering and Finance.
 Paint and Wallpaper.
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 Smith's Dock Monthly.
 South African Engineering.
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 Stone Trades Journal.
 Studio.
 Textile Manufacturer.
 Textile Recorder.
 Tropical Agriculture.
 Tropical Life.
 United Empire.

Watchmaker, Jeweller, and Silversmith.
 Water and Water Engineering.
 World Power.

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Agricultural Journal of India.
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NEWSPAPERS.

African World.
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 Home and Colonial Mail.
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 Times of India (Overland Weekly Edition).

MEETINGS OF THE SOCIETY BEFORE CHRISTMAS.

ORDINARY MEETINGS.

Wednesday evenings at 8 o'clock (unless otherwise announced).

NOVEMBER 7 (8.30 p.m.)—Opening Meeting of the One-hundred-and-seventy-fifth Session. Inaugural Address by SIR GEORGE SUTTON, BT., Chairman of the Council of the Society, on "Fifty Years of British Industry."

NOVEMBER 14.—OMAR RAMSDEN, R.M.S., "English Silver and its Future." RIGHT HON. THE EARL OF CRAWFORD AND BALCARRES, K.T., P.C., LL.D., F.R.S., P.S.A., will preside.

NOVEMBER 21.—EDWARD PERCY STEBBING, M.A., F.L.S., Professor of Forestry, University of Edinburgh, "Forestry in Sweden: its Importance to and Influence on Great Britain."

(Note.—The paper on "Safety in Factories," by Sir Gerald Bellhouse, C.B.E., which was announced for this date in the Prospectus, circulated to Fellows, has been unavoidably postponed).

NOVEMBER 28.—J. H. ESTILL, O.B.E., Commercial Manager, Port of London Authority, "The Port of London." RIGHT HON. THOMAS WILES, P.C., will preside.

DECEMBER 5.—SIR EUSTACE TENNYSON D'EYNCOURT, K.C.B., D.Sc., LL.D., F.R.S., "Fuel for Ships." HON. SIR CHARLES A. PARSONS, O.M., K.C.B., LL.D., D.Sc., F.R.S., will preside.

DECEMBER 12.—G. G. BLAKE, M.I.E.E., F.Inst.P., "Applications of Electricity to Medical Practice." SIR OLIVER J. LODGE, M.A., LL.D., D.Sc., F.R.S., will preside.

INDIAN SECTION.

At 4.30 o'clock.

FRIDAY, NOVEMBER 9.—JAMES WELBY MADELEY, M.A., M.Inst.C.E., "Town Water Supply in India." SIR HUGH TROWBRIDGE KEELING, C.S.I., will preside.

MONDAY, DECEMBER 3.—SIR JAMES MACKENNA, C.I.E., "The Sugar Industry of India." SIR REGINALD A. MANT, K.C.I.E., C.S.I., will preside.

DOMINIONS AND COLONIES SECTION.

At 4.30 o'clock.

TUESDAY, NOVEMBER 27.—COLONEL H. L. CROSTHWAIT, C.I.E., "Air Survey and Empire Development." SIR THOMAS H. HOLLAND, K.C.S.I., K.C.I.E., D.Sc., F.R.S., will preside.

FRIDAY, DECEMBER 14.—THE RIGHT HON. LORD OLIVIER, P.C., K.C.M.G., C.B., LL.D., "Negro Agriculture and What Can be Done With It." DR. ARTHUR WILLIAM HILL, C.M.G., Sc.D., F.R.S., will preside.

CANTOR LECTURES.

Monday evenings, at 8 o'clock.

FRANKLIN KIDD, D.Sc., Low Temperature Research Station, Cambridge, "Biology and Refrigeration." Three Lectures, November 12th, 19th and 26th.

LECTURE I.—Refrigeration and food preservation. A biological problem. The living organism and control of environment. The control of temperature. Other factors affecting behaviour. General relations between temperature and rate and character of change in animals and plants. Temperature coefficients. Low temperature effects upon plants and plant produce.

LECTURE II.—A detailed study of the apple as a type fruit. Pre-storage factors—race and nutrition. Storage factors—temperature, humidity, atmosphere composition, etc. Other fruits and other types of plant tissue. Practical aspects of storage, handling and transport of refrigerated produce in Great Britain, the Dominions and U.S.A.

LECTURE III.—The freezing of tissues. Super cooling. Effects dependent upon rate of cooling and thawing. Effects dependent upon condition of tissues. Changes occurring at low temperatures below freezing point of water.

MEETINGS OF OTHER SOCIETIES
DURING THE ENSUING WEEK.

MONDAY, NOVEMBER 12. Automobile Engineers, Institution of, at the Queen's Hotel, Birmingham, 7 p.m. Mr. L. H. Hounsfield, Presidential Address. "The Integrity of the Technical Man." Brewing, Institute of, at Charing Cross Station Hotel, Strand, W.C., 7.45 p.m. Dr. R. Seligman, "The Continuous Pasteurisation of Black Beers." Chadwick Public Lecture, at the Institution of Civil Engineers, Great George Street, S.W., 8 p.m. Mr. H. E. Stille, "Some Aspects of the London Water Supply." East India Association, at Caxton Hall, Westminster, S.W., 4.30 p.m. Mr. J. A. Richey, "Indian Education." Electrical Engineers, Institution of, Savoy Place, W.C., 7 p.m. Discussion on "Engineering Requirements of a Modern Office Building," opened by Mr. J. Coxon. Geographical Society, at Lower Lodge, Kensington Gore, S.W., 5 p.m. Captain J. G. Withycombe, "Lettering on Maps." Goldsmiths' Hall, Foster Lane, E.C., 7 p.m. Mr. W. W. Watts, "The Loan Exhibition of Oxford College Plate." Heating and Ventilating Engineers, Institution of, at the Borough Polytechnic, Southwark, S.E., 7.30 p.m. Mr. H. F. W. Joyce, "Space Occupied by Heating and Ventilating Apparatus."

Surveyors' Institution, 12, Great George Street, S.W., 8 p.m. Presidential Address of Mr. C. B. Fisher. University of London, at the Institute of Historical Research, Malet Street, W.C., 5.30 p.m. Major H. W. V. Temperley, "Jugoslavia." At King's College, Strand, W.C., 5.30 p.m. Rev. R. Hanson, "Medieval Scholasticism." At the London School of Economics, Houghton Street, W.C., 5 p.m. Don S. de Madariaga, "Disarmament." (Lecture II.) At University College, Gower Street, W.C., 5 p.m. Prof. E. B. Verney, "Urinary Secretion." (Lecture V). 5.30 p.m. Dr. Paul Stamberger, "Colloid Chemistry and its relation to the Rubber Industry." (Lecture I).

TUESDAY, NOVEMBER 13. Asiatic Society, 74, Grosvenor Street, W., 4.30 p.m. Prof. Dr. F. W. Thomas, "Some Documents and Languages from Chinese Turkestan." Automobile Engineers, Institution of, at the Broadgate Café, Coventry, 7.30 p.m. Dr. E. C. Wadlow, "The Comparative Merits of Road and Dynamometer Testing for Motor Vehicles." Electrical Engineers, Institution of, at the Hotel Metropole, Leeds, 7 p.m. Mr. W. B. Woodhouse, "Overhead Electric Lines." Manchester Geographical Society, 16, St. Mary's Parsonage, Manchester, 7.30 p.m. Major Wm. Cross, "Along Amazonian Forest Fringes."

- Marine Engineers, Institute of, 85-88, The Minories, E. 6.30 p.m. Major R. H. Mayo, "Air Transport."
- Mechanical Engineers, Institution of, at Swansea. Mr. W. Ogden Dayson, Chairman's Address.
- Petroleum Technologists, Institution of, at the Royal Society of Arts, Adelphi, W.C. 5.30 p.m. Mr. George Heseldin, "Drilling and Production Methods in the Greater Seminole Field, Oklahoma, U.S.A."
- Philosophical Studies, British Institute of, at the Royal Society of Arts, Adelphi, W.C. 8.15 p.m. Dr. Morris Ginsberg, "Race and Civilization."
- Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Prof. H. L. Callendar, "The Change of State from Liquid to Vapour." (Lecture III).
- University of London, at King's College, Strand, W.C. 5.30 p.m. Miss Evelyn Underhill, "The Philosophy of Contemplation."
- 5.30 p.m. Sir Bernard Pares, "Contemporary Russia." (Lecture VI).
- At University College, Gower Street, W.C. 5.30 p.m. M. Emile Cammaerts, "The Van Eycks." 6.30 p.m. Mr. Percy Dunsheath, "High Tension Transmission of Power." (Lecture I).
- WE, JUNE 14, NOVEMBER 14. Arts, Royal Academy of, Burlington House, W. 4 p.m. Dr. A. P. Laurie, "Chemistry." (Lecture I).—"The Theory of Colour and its Application to Painting."
- Chemical Engineers, Institution of, at the Institution of Civil Engineers, Great George Street, S.W. 6.30 p.m. Dr. Paul Klein, "Making Rubber Goods of Latex by Electro-Deposition."
- Civil Engineers, Institution of, Great George Street, S.W. 6 p.m.
- Literature, Royal Society of, 2, Bloomsbury Square W.C. Ordinary Meeting. 5 p.m.
- Mechanical Engineers, Institution of, at the Grand Hotel, Sheffield. 7.30 p.m. Mr. H. E. Yerbury, "Corrosion of Metals and its Prevention."
- Public Health, Royal Institute of, 37, Russell Square, W.C. 4 p.m. Mrs. R. H. B. Adamson, M.D., "The Health of Women and Girls in Relation to Industry."
- Radiology, British Institute of, at 1, Wimpole Street, W. 8.15 p.m. Prof. W. Lawrence Bragg, "X-Ray Optics." (Mackenzie-Davidson Lecture).
- United Service Institution, Whitehall, S.W. 3 p.m. Major-General C. P. Deedes, "The Influence of Ground on Modern Military Operations."
- University of London, at King's College, Strand, W.C. 5.30 p.m. Lieut.-Gen. Sir Herbert Holman, "The Army in India." 5.30 p.m. Dr. R. J. S. McDowall, "The Indebtedness of Industry to Pure Science." (Lecture V).—"Physiology and National Efficiency." At the London School of Economics, Houghton Street, W.C. 6 p.m. Mr. H. L. Rouse, "The Present Practice of the Midland Bank in the Uses of Office Machinery." At University College, Gower Street, W.C. 3 p.m. Dr. Camillo Pellizzi, "La Lirica del Paradiso." (Lecture II). 5.30 p.m. Dr. Paul Stamberger, "Colloid Chemistry and its relation to the Rubber Industry." (Lecture II) 5.30 p.m. Dr. John S. Owens, "Smoke Pollution of the Air and Public Health." (Lecture III). 5.30 p.m. Prof. Dr. J. G. Robertson, "Swedish Romanticism." (Lecture II). At the University Union Society's Rooms, Malet Street, W.C. 5.30 p.m. Dr. Julian Krzyzanowski, "Renaissance Poland." (Lecture VII).
- Wireless Technology, Institute of, at the Engineers' Club, Coventry Street, W. 7 p.m. Mr. B. H. J. Kynaston, "A Radio Fog Signal Alarm for Ship Stations"
- THURSDAY, NOVEMBER 15. —Aeronautical Society, at the Royal Society of Arts, Adelphi, W.C. 7.45 p.m. Mr. R. J. Penn, "Testing Aeroplane Engines in Flight—with special reference to Carburation and Carbureters." (Joint Meeting with Institution of Automobile Engineers).
- Antiquaries, Society of, Burlington House, W. 8.30 p.m.
- Arts, Royal Academy of, Burlington House, W. 4 p.m. Dr. A. P. Laurie, "Chemistry." (Lecture II).—"Early Methods of Oil Painting."
- Chemical Society, Burlington House W. 8 p.m. (1) Messrs. F. L. Gilbert and T. M. Lowry, "Studies of Valency. Part XII. Isomeric Derivatives of Diethyl Telluride." (2). Messrs. T. M. Lowry and F. L. Gilbert, "Studies of Valency. Part XIII. Further Experiments on the Molecular Structure and Configuration of the Quadrivalent Derivatives of Tellurium."
- Electrical Engineers, Institution of, at Trinity College, Dublin. 7.45 p.m.
- Linnean Society, Burlington House, W. 5 p.m.
- L.C.C., The Geffroy Museum, Kingsland Road, E. 7.30 p.m. Mr. Herbert Cescinsky, "English Oak Furniture of the 17th Century."
- Mechanical Engineers, Institution of, at the Hotel Metropole, Leeds. 7.30 p.m. Mr. H. R. Yerbury, "Corrosion of Metals and its Prevention."
- Metals, Institute of, at the Engineers' Club, Manchester. 7 p.m. Open Discussion on Standardization.
- Mining and Metallurgy, Institution of, at Burlington House, W. 5.30 p.m.
- North-East Coast Institution of Engineers and Ship-builders, at the Mining Institute, Newcastle-upon-Tyne. 6 p.m. Mr. J. Denholm Young, "Losses of Efficiency in Steamship Operation."
- Radiology, British Institute of, at the Central Hall, Westminster, S.W. 2.30 p.m. Dr. G. W. C. Kaye, Presidential Address, "X-Rays Medieval and Modern."
- Royal Institution, 21, Albemarle Street, W. 5.15 p.m. Captain G. Pitt-Rivers, "The Empire and the Native Problem."
- University of London, at Bedford College for Women, Regent's Park, N.W. 4.15 p.m. Prof. Eccles, "Pierre Corneille." (In French). (Lecture VII). At King's College, Strand, W.C. 5 p.m. Dr. W. Robson, "Protein Metabolism." (Lecture III). 5.30 p.m. Prof. J. B. Black, "Voltaire." 5.30 p.m. Mr. J. Isaacs, "Bunyan as a Literary Artist." (Lecture II). 5.30 p.m. Mr. Henry Wickham Steed, "The Making of Greater Roumania." At University College, Gower Street, W.C. 5.15 p.m. Prof. J. E. G. de Montmorency, "The Barbarian Codes as illustrating Social Life in Central and South-Western Europe from 450-750 A.D." (Lecture III). At the University Union Society's Rooms, Malet Street, W.C. 5.30 p.m. Prince D. Soyatopolk Mursky, "Tolstoy." (Lecture VI). At the Victoria and Albert Museum, South Kensington, S.W. 5.30 p.m. Mr. Eric Maclagan, "Donatello."
- FRIDAY, NOVEMBER 16. Auctioneers' and Estate Agents' Institute, 29, Lincoln's Inn Fields, W.C. Conference of Agricultural Members.
- Arts, Royal Academy of, Burlington House, W. 4 p.m. Dr. A. P. Laurie, "Chemistry." (Lecture III).—"Painting Media: Oils, Varnishes and Tempers." Dyers and Colourists, Society of, at Manchester. Dr. R. H. Pickard, "The Aims of recent Research at the Shirley Institute."
- Electrical Development Association, at the Royal Society of Arts, Adelphi, W.C. 7.30 p.m. Mr. H. T. Young, "Modern Lighting Designs for Domestic and Business Interiors."
- London Society, at the Royal Society of Arts, Adelphi, W.C. 5 p.m. Sir William Beveridge, "The Physical Relation of a University to a City."
- Mechanical Engineers, Institution of, Storey's Gate, S.W. 6 p.m. Dr. H. W. Swift, "Power Transmission by Belts: An Investigation of Fundamentals."
- University of London, at Bedford College for Women, Regent's Park, N.W. 5.15 p.m. Prof. E. Allison Peers, "A Century of Catalan Poetry." (Lecture I). At University College, Gower Street, W.C. 5 p.m. Prof. Dr. J. C. Drummond, "Recent Work on Vitamins." (Lecture VI). 5.30 p.m. Dr. Paul Stamberger, "Colloid Chemistry and its Relation to the Rubber Industry." (Lecture III). At the University Union Society's Rooms, Malet Street, W.C. 5.30 p.m. Prof. Dr. R. W. Seton-Watson, "The Collapse of Austria-Hungary." (Lecture VI).
- SATURDAY, NOVEMBER 17. L.C.C. The Horniman Museum, Forest Hill, S.E. 3.30 p.m. Mr. H. N. Milligan, "Missing Links" and Evolution."
- Royal Institution, 21, Albemarle Street, W. 3 p.m. Dr. W. G. Whittaker, "North Country Folk Music."

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